(PUBLISHED QUARTERLY)

Journal of the Council for Scientific and Industrial Research.

Vol. 6. FEBRUARY, 1933. No. 1.

The Work of the Council for Scientific and Industrial Research.

The article that follows consists of a radio address which was broadcast on the 14th December, 1932, by Senator the Hon. A. J. McLachlan, Vice-President of the Executive Council and Minister in charge of the Council for Scientific and Industrial Research. The address was broadcast simultaneously from stations 3LO Melbourne, 2CO Corowa, 2FC Sydney, and 2NC Newcastle.—Ed.

By courtesy of the Australian Broadcasting Commission, I am greatly privileged to be able to address you on the subject of scientific research.

Before I tell you something about the work of the Council for Scientific and Industrial Research, and the valuable results it has already achieved, I will just indicate very briefly the reasons why the Commonwealth Government considers that it is very important in the national interest to support this sphere of activity.

It is a truism that the prosperity of mankind depends very largely on the advancement of knowledge. Since the industrial revolution, we have seen a whole succession of fundamental discoveries in science, resulting in the establishment of innumerable new industries, in revolutionary changes in the habits of man, and in the development of a completely new social order. During the past 150 years, the progress made in our command over nature, and in the improvement of the conditions of mankind in civilized countries, has been immeasurably greater than in all preceding years.

The fact that science is recognized as the foundation of the whole fabric of modern society need hardly be elaborated. One or two outstanding examples will suffice to illustrate that point.

The discoveries of Faraday were all made in the laboratory, and were believed originally to be of no practical importance, yet in his discoveries lay the germ of all the dynamos and the great systems

of electric power transmission of the present day, including the electric railways and tramways, without which modern transport would be impossible. The researches of Pasteur were commenced entirely from the point of view of pure science, and it was only later that he took up the application of his results first to fermentation problems and then to the control of disease. The discovery of electric waves which now broadcast information and entertainment over the earth arose from a mathematical investigation by Clerk Maxwell, and it took 20 years to bring these waves out of the realm of mathematical formulae into the realization of fact. The discoveries in heredity and cross-breeding, which were made initially by Mendel, and which have added millions to Australia's wealth, originally had no industrial objective in view. All these, and innumerable other fundamental discoveries, have reacted in an extraordinarily favorable way on the well-being and comfort of mankind.

One of the striking developments of recent years has been the recognition by Governments of the part played by scientific research as one of the most important factors of national welfare. In many countries, national scientific research institutions have accordingly been established for research in applied science in connexion with the more important industries of the particular countries concerned. In Australia, it is only too evident that an extraordinary number of important national problems exist. The rapid spread of imported pests, such as the prickly pear, the blowfly, and the buffalo-fly, when removed from their natural habitat, and from the factors that there kept them in control, is amazing. The breeding of plants of economic value capable of being grown in the drier parts of the continent; the development of methods whereby greater quantities of Australian-grown perishable foods can be placed on the markets of the world; means whereby our great timber resources can be utilized to best advantage; the examination and classification of our soils so that they may be profitably cultivated; the investigation of scientific problems affecting our great irrigation settlements; the control and eradication of animal diseases and other problems so vitally affecting our great pastoral industries, constitute other groups of problems which exist not only in one State of the Commonwealth but in every State.

Much work in regard to many of these problems has been carried out, and in this connexion a tribute is due to the magnificent efforts which have been made by State Departments of Agriculture, of Mines, of Forests, &c., and by the various Australian Universities. Nevertheless, it is quite clear that if our splendid opportunities are to be fully realized, Australian effort in the field of scientific research must be intensified.

In 1926, the Government accordingly decided to place the Council for Scientific and Industrial Research on a proper and effective footing, and it is pleasing to be able to record that that action, as well as the continued support of the Council, has received the general commendation of every party in the Federal Parliament, as well as approval and co-operation from very many outside organizations.

Our scientific research costs, from Government sources, between £60,000 and £70,000 per annum. This figure is most insignificant as compared with the expenditure of other countries. In England, for

example, in 1931, the sum of £87,000 was provided for the Fuel Research Board alone; £105,000 for the National Physical Laboratory; £38,000 for the Building Research Board; £68,000 for fisheries research; and £464,000 for agricultural research.

The figures for the United States of America are even more striking. In that country the Federal Department of Agriculture expends about £6,000,000 per annum on research, to which must be added very considerable expenditure on the part of the various States; the Bureau of Standards costs about £880,000; and the total funds voted to research by various American industries has reached the astounding figure of £40,000,000 per annum.

In Canada, the sum of £600,000 was expended recently on the construction of governmental research laboratories alone. Many other striking figures could be quoted in relation to other countries, like Japan, Germany, and so on, but for present purposes, the few illustrations which I have quoted serve to show the importance with which the world views scientific investigation.

To all those who are engaged in waging a gallant struggle against economic adversity, like the primary producer, I would especially stress the importance of science. At Ottawa, we obtained preferences for Australian products, but these advantages will be nullified, unless the quality of our products can be maintained at a standard competitive with that of other countries. This can be achieved only by the adoption of scientific processes.

The possible scope of the Council's investigations is very wide indeed, and having regard particularly to the amount of money and the supply of trained investigators available, the Council had soon after its creation to decide on the branches of work on which its efforts should primarily be concentrated. The principal work has accordingly been organized in the following groups or sections:—(i) plant industry; (ii) economic entomology; (iii) animal health; (iv) animal nutrition; (v) soils and irrigation; (vi) forest products; and (vii) preservation and transport of foodstuffs.

A great deal of the Council's work is carried out in close co-operation with other organizations, such as the State Departments of Agriculture, Universities, the Waite Agricultural Research Institute, and so on. The Council has, in fact, succeeded in bringing about a full measure of real co-operation among the bodies concerned with scientific industrial research throughout Australia. This has been achieved largely through the State Committees, which have been established in each State, and through the Standing Committee on Agriculture, which comprises amongst its members the permanent head of each State Department of Agriculture.

Nevertheless, it was obviously necessary for the Council to have certain research laboratories of its own. Laboratories for plant research and entomological investigations have been established at Canberra. At Adelaide, there are the Animal Nutrition and the Soils Laboratories—the former located in the grounds of the University of Adelaide, and the latter housed in a building made available by the generosity of the Darling family. At Sydney, there is the McMaster Animal Health

Laboratory, erected and equipped from the munificent gift of Mr. F. D. McMaster. At Melbourne, there is the Forest Products Laboratory. At Brisbane, there is the Cold Storage and Food Preservation Laboratory—the gift of the Queensland Meat Industry Board. Near Townsville, there is a laboratory for the investigation of animal health problems affecting cattle in North Australia. Then at Merbein, in Victoria, there is a research station for the investigation of problems affecting our dried vine fruits, and at Griffith, New South Wales, another research station for work on problems connected with the citricultural industry.

At its Plant Industry Laboratory, at Canberra, the Council is giving special attention to plant diseases, which cause an annual loss in Australia of £12,000,000 sterling. Already, results of very substantial value have been obtained. For example, the investigation on bunchy-top in bananas, a disease which was devastating our banana plantations, gave results which have been applied so successfully by the New South Wales and Queensland Departments of Agriculture that the banana industry has now been re-established on large areas in those States. Bitter pit in apples, which was so serious a menace to our export apple industry, has been shown to be intimately related to immaturity at picking time, and the annual loss of £100,000 in export apples may now be reduced to negligible proportions. Blue mould in tobacco, which often completely destroys tobacco crops in many parts of Australia, is being investigated, and already results having an important bearing on the control of the disease have been obtained. A commercial method of getting rid of water blister of pineapples, which causes a loss of £12,500 per annum, has been discovered. Spotted wilt in tomatoes, flag smut and root rots in wheat, and other diseases are being attacked, and good progress is being made.

At the Entomological Laboratories, one section is concentrating on the control and eradication of weed pests by introducing from abroad insects which destroy them. Insects which attack St. John's wort have been discovered, introduced, and acclimatized, and many thousands of them have been distributed in New South Wales and Victoria. Insects which attack Noogoora burr have been found in America, and already one species has been introduced into Australia. Consignments of a moth which destroys ragwort have been obtained from New Zealand, and have been liberated experimentally. As regards insect pests, a group of entomologists has been concentrating on the buffalo-fly pest, which is so serious a menace to Australia's cattle herds, and parasitic insects have been brought from the Dutch East Indies. The sheep blowfly pest is also being tackled vigorously, and already good progress has been made, particularly in the acquisition of a large amount of fundamental knowledge regarding the various species primarily responsible for attacking sheep.

Another important group of national problems which is being tackled by the Council is that relating to diseases of stock, particularly sheep and cattle. Perhaps the outstanding achievement in these investigations is the discovery and practical application of a vaccine against black disease of sheep, which is estimated to cause an annual loss of £1,000,000. The cause of the Beverley disease of sheep in Western Australia has been discovered, and a vaccine which has been evolved has given very satisfactory results. Successful results have also been obtained from the parasitological investigations which are now centred

at the F. D. McMaster Laboratory, in Sydney. At the Animal Health Research Station recently opened near Townsville, a number of important problems affecting cattle in Northern Australia are being investigated.

At its Animal Nutrition Laboratory, at Adelaide, the Council is concentrating its work almost entirely on a fundamental study of sheep with a view to building up a body of knowledge which will enable definite guidance and advice to be given to pastoralists so as to enable them to overcome certain serious difficulties with which they are faced. As a result of field trials in Queensland, it has been shown that under certain conditions it is possible to obtain an increase of over 30 per cent. in the weight of the fleece, at a relatively small cost. In certain parts of Australia the pastures are deficient in various mineral constituents which are essential to the well-being and growth of sheep, and investigations are being carried out in order to determine how these difficulties can best be overcome. Another important section of the nutrition work is that relating to the feeding of sheep in times of drought. The object of these investigations is to obtain full information regarding the amount of energy contained in various foodstuffs, their digestibility, and price. In this way the most economical methods of hand-feeding during periods of drought will be determined.

Investigations on soil problems have been concentrated mainly on the irrigation settlements, with the objects, firstly, of advising settlers as to the methods to be adopted in order to make their areas more productive, and secondly, to make investigations of the soils of virgin areas for future settlement. The survey work in the Murray River settlements will be completed in about two years' time, and the results obtained show not only that much of the loss on these settlements could have been avoided had the necessary investigations been made, but also that future developments in irrigation settlement can be undertaken with a full knowledge, so far as suitability of soils is concerned, of the conditions essential for successful production.

The dried fruits industry of Australia has an annual turnover of over £3,000,000, and the viticultural and citricultural industries have led to the establishment of thousands of homes in the irrigation areas, and to the expenditure of large sums of money on dams, channels, pumping stations, &c. Since the establishment of the Council's Research Station at Merbein, the yield of dried fruit per acre has been more than doubled, and this increase has been accompanied by a substantial improvement in quality. It may, in fact, be claimed that the present satisfactory condition of the industry is in no small degree due to the results of the Council's work, which results are each year becoming more and more generally applied, with consequent improvements in yields, processing methods, and quality, and enhanced prices for the products. An outside estimate has assessed the added value of the dried fruit crop at £8 per ton as the result of the work of the Merbein Research Station. Similarly, the work at the Citricultural Research Station, Griffith, is yielding most valuable results. The experiments have shown that citrus fruit yields can be profitably increased by the adoption of certain cultural and manurial methods, and these methods are now becoming the standard practice on the Murrumbidgee Irrigation Area, with a consequent increase in productivity, and reduction in cost.

The recently formed Division of the Council dealing with forest products problems, with its laboratory at Melbourne, has already achieved very great success. It has been instrumental in bringing about improvements of material value in many directions. As an example, the work on the use of Australian timbers for the manufacture of butter boxes may be mentioned. Frequent complaints have been received in the past that butter exported in boxes of Australian wood developed wood taint. Most Australian butter is at present exported in boxes of New Zealand white pine. The experiments have been most successful, and a rapid and cheap method has been developed for treating timber so as to prevent taint. The method is now being tested by semi-large scale shipments of butter to England. It is probable that the investigations will lead to the utilization of very large quantities of Australian timber in place of that at present imported.

Another important development is the establishment of an industry in Western Australia for the production of tannin extracts from waste karri and marri barks. This industry is based directly on the results of the research work of the Council, and is a gratifying conclusion to years of experiment. It is anticipated that the industry will develop an extensive export trade. A third development of great importance appears to have resulted in a definite promise of the establishment of the paper-making industry in Australia. In spite of the Council's successful work on the manufacture of paper-pulp from Australian timbers, it has for long been impossible to get any acceptance of the fact that our hardwoods can be used for the manufacture of paper. Difficulties are now being overcome, and the way is clear for the establishment of what may develop into one of our most important industries. Very satisfactory work, of much value to our timber industries, has also been done in the seasoning and preservation of Australian timbers, and in their utilization for many industrial purposes.

Until recently, the Council's investigations into problems connected with the preservation and transport of foodstuffs, particularly by cold storage, has been confined largely to isolated problems which, though yielding valuable results, were difficult to co-ordinate, and did not adequately cover the field of urgent investigations required. Though it had long been the intention of the Council to develop this field of investigation in view of its great importance, particularly to our export industries, lack of funds and of trained scientific investigators prevented the formation of a suitable organization. However, recently the Council has been able to establish a small section to deal in a more systematic way with these problems. At the laboratory at Brisbane, the problem of the export of chilled beef is being intensively investigated. The importance of this work lies in the fact that, owing to the longer voyage to England, Australian beef has to be frozen, and does not fetch so high a price on the London market as Argentine chilled beef. An investigation is also being conducted on problems connected with the export of pig carcasses to England for the manufacture of bacon. Work on the ripening and storage of bananas has been very successful, and the results are being adopted commercially. In Melbourne, work is in progress on the storage and transport of oranges, apples, and other non-tropical fruit.

Perhaps the most spectacular success achieved is in the destruction of prickly pear. This work was undertaken at the instance of the old Advisory Council of Science and Industry, and is being carried out

by the Commonwealth Prickly Pear Board. It is well known that already heavy growth of pear has been destroyed on millions of acres, and whilst there are certain aspects of the problem, such as the destruction of re-growth from the butts and roots of the old plants, the attack of parasites of *Cactoblastis* insects, and the destruction of the dreaded tiger pear, which still require close attention, there is reason to believe that in the course of a few years Australia will have succeeded in ridding itself of this great invasion, which constitutes the worst plant pest the world has ever known. Already areas previously covered by pear are being brought back into cultivation, and when it is realized that the prickly pear belt extends to no less than 60,000,000 acres, the enormous value of this extraordinarily successful work will be realized.

It is impossible to express in pounds sterling the value of the results already achieved, but it is very clear that it is many times greater than the total cost of the investigations. In fact, no type of effort is capable of returning higher dividends than scientific industrial research, particularly when applied to our primary industries. One of the most gratifying features of the Council's work is the evidence of appreciation it has received in the way of substantial grants, both in money and kind, from many commercial and industrial interests.

The Present Position and Future Prospects in Relation to the Biological Control of Prickly Pear.

*By Alan. P. Dodd.**

The report that follows has been prepared by the Officer-in-Charge of the Commonwealth Prickly Pear Board's investigations, and has been made available by that body for publication. The Board is financed by contributions from the Council for Scientific and Industrial Research and the States of Queensland and New South Wales in the proportion of 2:1:1. At present, it is constituted as follows:—W. L. Payne (Queensland Department of Lands), (Chairman); G. Lightfoot (Council for Scientific and Industrial Research); Professor E. J. Goddard (Council for Scientific and Industrial Research); and G. D. Ross (New South Wales Department of Agriculture).

The work described in the report has been particularly successful, and quite an outstanding instance of the economic value of scientific research. This will be obvious when it has been seen from the report that the original pear infestation of 60 million acres—an area slightly larger than the whole State of Victoria, and also very little less than the total area of Great Britain and Northern Ireland—has all been attacked, and that with care there is every prospect of entirely ridding Australia of the pest in a comparatively short time. Science can thus fairly claim to have almost redeemed to Australia, and at a comparatively infinitesimal cost, a province of the size of the State of Victoria, and one which bade fair to become utterly useless.—Ed.

Summary.

The past three years have brought a very great change in the prickly-pear situation. Widespread destruction of the pest has followed the general establishment of *Cactoblastis*, to such an extent that the greater part of the original pear has collapsed in Queensland and the northern areas of New South Wales. In Queensland a vigorous policy of the development of pear lands for closer settlement is being pursued—a wonderful tribute to the efficiency of insect destruction.

But there is still particular need for scientific research and investigation. Re-growth, which invariably springs up after the initial collapse of prickly-pear, is a feature of the situation in many districts. Although *Cactoblastis* destroys this secondary wave of the pest readily, the Board is making a special endeavour to establish other insects for its more rapid control. Natural parasites kill a percentage of the *Cactoblastis* population; mortality from these agencies is not a serious factor and does not appear to be increasing; nevertheless, the question demands continued study. In the Hunter River districts of New South Wales, insect destruction has been much slower than elsewhere, but is now giving promise of eventual success.

The tiger-pear, *Opuntia aurantiaca*, which spreads very rapidly, is being made the subject of a special investigation for the introduction of its particular insect enemies. The tree-pear (*Opuntia tomentosa*) position in Central Queensland is being watched carefully.

In conclusion, it should be emphasized that the biological control of prickly-pear has been, up to the present, an outstanding success—a success that could hardly have been visualized five years ago.

1. Progress to May, 1929.

The last publication by the Board dealt with the progress of the biological control investigations to May, 1929. At that time, cochineal was generally established throughout the pear areas: it had considerably

* Officer-in-charge of the Commonwealth Prickly Pear Board's Investigations.

reduced the height and density of the pear infestation in the heavily-timbered brigalow and belar scrubs, and had brought about very effective destruction of *Opuntia stricta* in Central Queensland. The prickly-pear red spider, *Tetranychus opuntiae,* had co-operated with cochineal in the thinning out of the dense pear in the scrub areas. The plant bug, *Chelinidea tabulata,* was established in enormous numbers at many points, where it was assisting to control the fruit and new growth of the pear. The large-scale distribution of *Cactoblastis cactorum* had been commenced; around some of the centres where the earliest experimental liberations in 1926-27 of this insect had been placed, the destruction of the pest over areas of from a few to 1,000 acres indicated, in some degree, the remarkable progress that might be expected in the near future. But the greatest success had been achieved in the virtual checking of the spread of the pest, a huge increase estimated at nearly 1,000,000 acres annually, as a result of a combination of insect activities and of energetic poisoning methods adopted or enforced by the State prickly-pear organizations.

2. Progress since May, 1929.

The campaign of *Cactoblastis* distribution was carried out on a most extensive scale by co-operation between the Board and State authorities, and was practically completed by the end of 1930, when 3,000,000,000 eggs of this insect had been released throughout the length and breadth of the entire pear area of Queensland and New South Wales, either by direct Government action or through supplies given free of cost to land-owners. So quickly did *Cactoblastis* become established that, by the end of 1931, it could be said that it existed on practically every acre of the tremendous pear infestation of both States; and so rapidly did it increase that widespread collapse of the primary pear followed its activities in every district except the more southern pear area of New South Wales.

Thus the past three years have witnessed a very sudden change in the prickly-pear situation. The success of *Cactoblastis* has been most spectacular. Over enormous areas the original dense pear, that had flourished unchecked for years, has been destroyed. This statement is not intended to convey the impression that the pest has been completely annihilated, for a secondary growth is present in greater or less degree; the re-growth question will be discussed more fully in a special section of this review. As an example of the remarkable progress achieved by *Cactoblastis,* one instance may be given. In August, 1930, the continuous and almost unbroken pear belt along the Moonie River, Southern Queensland, showed for 150 miles no destruction, and so light an infestation of *Cactoblastis* that further distribution was considered. However, the increase of this insect was so rapid that in August, 1932, two years later, 90 per cent. of the primary pear had disappeared. In Queensland, the chief remaining large belt of the two pest pears, *Opuntia inermis* and *Opuntia stricta,* is between Goondiwindi and the Moonie River. Probably 80 per cent. of Queensland's dense primary pear has been destroyed. Very fine results have been achieved in the North-west and the Pilliga State Forest areas of New South Wales; it is estimated that the primary pear has been reduced in all pear districts of that State, excepting the Hunter Valley and Camden districts, by from 50 to 60 per cent.

But as the effectiveness of *Cactoblastis* has increased, that of the other pear insects has diminished. The dense concentrations of *Chelinidea tabulata* have decreased in the past two years to rather scattered numbers. Red spider, as an effective controlling agency, no longer counts. The sphere of usefulness of cochineal has been restricted to the sporadic destruction of new growth. The favorable results at the present juncture can be attributed mainly to the work of one insect, namely, *Cactoblastis*.

3. Reclaiming of the Land.

The Queensland Government immediately took advantage of the first widespread destruction of prickly-pear to promulgate a comprehensive scheme for the development for pastoral, grazing, and agricultural purposes, of land retrieved from the pest by insect agency. The programme is being pushed forward expeditiously. Already 1,514,881 acres of pear land have been re-selected for mixed farming operations, and 1,701,308 acres for grazing, all with development conditions. Ring-barking and falling of the useless timber, the clearing of roads and fence lines, and the erection of fences are proceeding apace. The homes of new settlers have made their appearance. Artificial grasses are being sown as the clearing of the timber progresses. Crops have already been grown successfully.

This marked evidence of progress is an outstanding tribute to the success of the biological control campaign. Within the next few years, great areas of former useless pear land will be brought into productiveness. The many new settlers will mean the growth of townships within the former prickly-pear area. Indeed, at Chinchilla, a new butter factory, shops, &c., already point to greater expansion in the near future.

The development of pear lands, except in the case of a few small areas, has been possible within the past two years only. Hence the work of bringing the reclaimed land into productiveness is as yet in its initial stages.

4. The Other Side of the Picture.

The spectacular destruction of *Cactoblastis* has tended to give the impression that the prickly-pear problem has been completely solved, and that no further research work is necessary. When the extent of the collapse of the primary pear is realized, and when mile after mile of dead and rotting pear is viewed, the tendency to magnify the admittedly wonderful results and to overlook the incompleteness of the destruction is natural. It is therefore necessary to point out in what manner the destruction is incomplete, and to indicate the many aspects of the problem that require continued attention.

(i) *Re-growth.*—Care has been exercised in the foregoing sections of this article to distinguish the destruction by *Cactoblastis* as the collapse of the primary or original prickly pear. But this destruction, spectacular as it has proved, is far from meaning the complete annihilation of the pest. Immediately after the initial collapse of the pear, one sees nothing but dead pear for a few months. The butts and roots, however, have not

been completely destroyed, and when the growing season of the plant, September-December, arrives, re-growth appears. A secondary growth is not peculiar to insect destruction, for it invariably springs up after poisoning operations among dense pear.

In the early days of *Cactoblastis* progress, re-growth was not a pronounced feature. The separate areas of destruction were not extensive, and the insect population in the surrounding standing pear soon overflowed on to the new growth, and brought about its control rapidly. But when the activity of *Cactoblastis* encompassed the collapse of the whole or major portion of the primary pear in a district, the population of the insect suddenly dropped through starvation to very low numbers, and the small residue was quite inadequate to destroy the recurring growth immediately.

The first big wave of re-growth arose in the early summer of 1930. In many areas, it was subjugated during the summer by *Cactoblastis,* which occurred in very large numbers in other portions of the same districts. However, in the Chinchilla district, the vigorous re-growth flourished unchecked throughout 1931; the *Cactoblastis* infestation, at first very light, increased in each succeeding generation, and the new growth was brought under control in the 1932 winter, or nearly two years after its appearance.

Another example of the control of re-growth may be given. In December, 1931, a very dense and vigorous re-growth over several thousand acres on the eastern side of the Mungle Scrub, New South Wales, had reached the fruiting stage. The *Cactoblastis* population, which must have been light indeed eighteen months earlier, was now most satisfactory. Six weeks later, at the end of January, 1932, the whole of this re-growth had collapsed.

Following the great advance of destruction of primary pear, the recurring growth of the 1931 summer involved very considerable areas. Much of this secondary wave of the pest still flourishes, fifteen months later, and in places has recently flowered and fruited. However, *Cactoblastis* is present wherever re-growth occurs. This succulent type of pear is the most favorable medium for the rapid increase of the insect, and there is no reason to expect that the control of existing areas of re-growth will not be brought about within a short space of time. In Central Queensland, for some reason, possibly because of dry winter and early summer months, re-growth has not attained dense proportions, and has not escaped, even if temporarily, the attention of *Cactoblastis.*

In June, 1931, the Board decided that, although the prospects of control by *Cactoblastis* were exceedingly hopeful, it would be unwise to leave the eventual control of re-growth to *Cactoblastis* alone. Hence a programme for the introduction of new strains of cochineal was commenced. Supplies of these insects have been secured from several places in America, and are being reared, with a view to their distribution in the near future. Furthermore, an endeavour is being made to import from North America a particular insect, *Mimorista,* the caterpillars of which feed on young growth solely. With these insects co-operating with *Cactoblastis,* it is hoped that more rapid control of re-growth may be brought about.

(ii) *Natural Enemies of Cactoblastis.*—The future of *Cactoblastis* depends upon the extent of the controlling influences exercised by disease and parasitic agencies. Disease organisms are always present among the larvae, and have at times assumed serious epidemic proportions. However, as outbreaks are sporadic, and appear to be restricted to localities where the larvae are heavily concentrated, diseases are unlikely to bring about control of this insect.

Several native parasites have already turned their attention to *Cactoblastis,* and two have assumed some importance. The investigation of the habits and the controlling effect of these parasites is an important phase of the Board's work. Records of the degree of parasitic attack are gathered from many different localities, in order that the general position in the various districts may be gauged. At present, the control by parasites averages 15 per cent. in Central Queensland and north-west New South Wales, 5 to 10 per cent. in southern and south-west Queensland, and 20 per cent. in the Hunter River district, New South Wales. Thus, parasites are not exercising any important degree of control. In the past two years, the percentage of mortality from parasitic attack has not increased, and there is no reason to anticipate that it will increase in the future. If *Cactoblastis* were ever to be rendered impotent, it would mostly probably be due to the controlling action of parasites. Hence it is essential that scientific observation and investigation should be maintained on this important question.

5. Other Problems.

The re-growth situation, and the extent of parasitism, may be considered the main questions of the future, since they are pertinent to the whole of the prickly-pear area. There are, however, various other problems of a more or less sectional nature.

(i) *The Hunter River Situation.*—Although large-scale destruction of prickly-pear is being secured over the major portion of the infested area, there are certain districts where *Cactoblastis* and other prickly-pear insects have not given entirely the same favorable results. The largest of these sections is the Hunter River Valley, where the dense pear infestation occupies probably 2,000,000 to 3,000,000 acres. The Hunter River situation has been, for the past two years, the subject of a special investigation by the Board. It has been ascertained that the slower progress of *Cactoblastis* is due to a combination of climatic factors and of soil conditions affecting the greater portion of the pear in this area. Until 1931, the results of the extensive distribution of *Cactoblastis* had been disappointing, in that the insect had failed to become established generally. In the past eighteen months, however, *Cactoblastis* has made appreciable progress; areas of destruction, somewhat limited in extent, occur at various points, while a light infestation has become fairly general throughout the district. It is hoped that this progress will continue, and that eventually the Hunter River pear will be brought under control.

(ii) *Tiger-pear (Opuntia aurantiaca).*—This plant occurs in many places in Queensland and New South Wales. Although the total infestation is not very great, possibly not more than 25,000 acres, it is

increasing rapidly, the rate of spread being much greater than that of the main pest pears. Moreover, the application of poisoning methods has not succeeded in coping with this dangerous plant, which is a very serious pest in South Africa.

Cactoblastis will destroy the upper growth, but not the underground bulb. The recuperative powers of the plant are so great that a few months after its apparent destruction it has regained its former size. When the failure of *Cactoblastis* to control this pest had been ascertained, the Board despatched two officers to South America eighteen months ago to undertake a special investigation of the insect enemies of *O. aurantiaca* and its near allies. A strain of cochineal attacking *O. aurantiaca* has recently been received from the Argentine, where other insects are being studied, with the view to their early introduction into Australia.

(iii) *Tree-pears.*—Extensive areas of tree-pears, *Opuntia tomentosa,* and *O. streptacantha,* more particularly the former, occur in Central Queensland. In the case of *O. streptacantha,* a special strain of cochineal from Mexico is succeeding in destroying the young plants, and is causing damage to the large plants.

As regards *O. tomentosa, Cactoblastis* will destroy the young plants, but will not attack the larger plants. The control of the seedling plants would seem assured while *Cactoblastis* is present on *stricta* and *inermis* in the same district, since there is always a suitable food supply for the caterpillars, and the resulting moths will deposit eggs on any young *O. tomentosa* plants that may arise. Hence, the spread of tree-pear is prevented, and the large plants must gradually die of old age. But, in the event of the *O. stricta* and *O. inermis* infestation being eradicated, the control of young tree-pear may cease, and it may become necessary to take further steps toward the introduction of particular insect enemies of this plant.

The Acidity of Cream and the Keeping Quality of Butter made from it, with Special Reference to the Neutralization of Cream.

By W. J. Wiley, M.Sc.

From time to time in recent years, various authorities have stressed the need for further research work into problems of the Australian dairying industry. After a very extensive inquiry into all aspects of that industry—the importance of which may be gauged from the fact that it is responsible for a return of some £10,000,000 per annum from butter exports alone—the recent Federal Dairy Investigation Committee reported that, in addition to research work in pastures, diseases, &c., there was need "for a research service in dairy bacteriology and biochemistry which would investigate problems of a more fundamental character which are common to all States."

It had accordingly been hoped that with the completion of Mr. Wiley's work on the prevention of wood taint in butter, it would have been possible to provide the necessary funds for further work on other problems connected with butter production. One such problem is the determination of the best degree of acidity to adopt in the case of butters intended for the export trade. As a preliminary to some work on that matter, Mr. Wiley has spent some time reviewing the literature dealing with the effect of acidity on the keeping qualities of butter. Unfortunately, it has not been possible for the Council, with its limited resources, to finance further work, but, as the above-mentioned review may be of some interest, an article based on it has been prepared by Mr. Wiley, and is published below. Those specially interested would be able to peruse the more detailed review at the Council's head office.—Ed.

Summary.

1. The results of some of the more important of the published results on the acidity of cream and the keeping quality of butter prepared from it have been reviewed.

2. The subject of cream neutralization has been briefly reviewed, and some theoretical aspects of the subject discussed.

3. The results of a recent examination of 70 samples of butter are given, and show the lack of standardization in the acidity.

1. Introduction.

In the last year, 91,086 tons of butter, valued at over £10,000,000, were exported from Australia, and the greater part of this would not reach the ultimate consumer's table until at least two months after manufacture, and might even be held for a considerably longer period. The necessity of Australia manufacturing butter of particularly good keeping quality is thus obvious.

It speaks volumes for modern methods of manufacture and control that most of these export butters deteriorate very little during the necessary storage. The gross causes of deterioration have been studied and largely eliminated, but there is still considerable discussion over the more detailed aspects of the subject. For instance, although the fact that high acid butters do not hold up on storage is well known, the exact degree of acidity desirable is not so well established.

The acidity of the butter is a factor influencing the chemical changes taking place even at cold storage temperatures. A large amount of practical experimental work has been published on this subject, and probably even more not published. Very little, however, has been done on the theoretical aspects, and beyond such vague generalities as that acidity favours fat hydrolysis, thus leading to greater susceptibility to oxidation, the precise reasons for the profound effect of what is after all a quite small acidity in even the most acid butters have not been established. Practical work has been stimulated by the fact that low acidity of the butter and the choicest flavour of the fresh product are, to a certain extent, antagonistic. Butter churned from sweet cream lacks the flavour and aroma-producing substances which many people consider essential for the choicest product. When these are developed by cream ripening, the acidity inevitably produced spoils the keeping quality of the butter. In some factories where sweet cream is received, this has led to the practice of ripening and then neutralizing the acidity to ensure good keeping quality and still leave some of the flavour of the ripened cream butter. Where the cream is received already sour, neutralizing is essential to obtain keeping quality.

It has been mentioned that although the deleterious effect of high acidity is well known, the most desirable acidity is not so well established, and wide differences of opinion exist among butter-makers on the subject. It is the purpose of this article to describe briefly some of the more important experimental work which has been published on the subject. Unfortunately, most of that work which gives full experimental details has been done in other countries, and may not be applicable in detail to Australian conditions.

Obviously it is the acidity of the butter that affects its keeping qualities, and the only control over this the butter-maker has is the acidity of the cream, so that practically all the work has been done on the acidity of the cream at churning time. The experiments divide themselves into two groups, those where the cream acidity has been obtained by ripening, and those where the cream has first become sour and then neutralized to the desired figure. The best acidity for keeping quality may not necessarily be the same for the two methods.

2. The Keeping Quality of Butters from Un-neutralized Creams of various Acidities.

As early as 1890, several authors had reported the superior keeping qualities of sweet cream butter. The work of Rogers and associates (1909-1913) definitely established this, and indicated the factors influencing the changes during cold storage of butter. The oxygen content of the butter was found to decrease, and when excess air was worked into the butter, deterioration was accelerated. It was suggested that the off flavours produced might be at least in part due to oxidation of lactose, and this would be accelerated by lactic acid, because of inversion of the lactose. The catalytic effect of traces of copper and iron was fully established. It should be noted that Rogers found that lactic, hydrochloric, or acetic acids added to bring the acidity from 0.22 to 0.45 per cent. to sweet pasteurized cream of acidity 0.13 per cent. caused

similar deterioration to that produced by lactic acid from natural ripening. The increased oxidation due to acidity, therefore, is not a specific effect of lactic acid, but rather an effect due solely to acidity.

Rogers also found that high acidity and salt concentration led to the taint of fishiness and Supplee (1919), Cusick (1920), and Sommer and Smit (1923) confirmed this, and showed that trimethylamine, which is produced by the hydrolysis of lecithin, is responsible for the fishy flavour. O'Callaghan (1907) claimed that salting had nothing to do with fishiness, and that it was due to the mould *Oidium lactis* growing in conjunction with *B. acidi lactici*. It is interesting to note that he stated that "the terror of the Australian butter grader is that form of decomposition which is accompanied with a fishy flavour." With the subsequent adoption of neutralization and pasteurization of cream, this taint has lost much of its importance in Australia.

Dyer (1916) studied the chemistry of the deterioration in cold storage butter by measuring the change in composition of the gas enclosed within the butter. He found very little change in the oxygen content of butter made from sweet cream or sweet cream plus starter (0.25 per cent. acidity) after storing six months at 0 deg. F. When the cream was acidified with lactic acid to an acidity of about 0.7 per cent. before churning, there were pronounced changes in the gases on storage, the oxygen content decreasing. Pure butter-fat did not absorb appreciable quantities of oxygen on storage, while butter intentionally made to contain more than the normal proportion of non-fatty solids absorbed oxygen. In none of the experiments were the chemical constants of the butter-fat appreciably altered. Dyer concluded that these results indicate that the non-fatty solids rather than the fat are concerned with the deterioration of storage butter from acid cream. It is possible, however, that the non-fatty solids and acidity exert a catalytic effect in the oxidation of the butter-fat, and that their presence is necessary for appreciable oxidation under the conditions. For instance, Briggs (1931) found that lactic acid has a pro-oxidative effect on butter-fat, although he found curd to have an anti-oxygenic action. The absence of change in the analytical constants of a fat cannot be taken as proving that there has not been sufficient chemical action to affect the flavour materially. Changes in flavour can be detected long before there is any appreciable alteration in the usually determined fat constants. Dyer's results, however, definitely showed the more rapid oxidation of some butter constituent with increased cream acidity.

Hunziker and Hosman (1917), in a study of tallowy butter, ascribe this fault to glycollic acid produced by the oxidation of glycerol or lactose. They do not state that this fault is most common in butter from high acid cream, but claim it to be produced when the butter is made from an alkaline cream. It may here be mentioned that tallowy flavours are now generally considered to be due to oxidation of the fat, commencing at the double bonds in oleic or linolenic acids present, although the exact mechanism is not thoroughly understood. While this is undoubtedly true for a pronounced tallowy flavour, accompanied by bleaching of the fat, it is by no means established that the comparatively mild taints, sufficient, however, to degrade the butter, and termed "tallowy," are due to the same cause. These can be detected before

the butter-fat gives a positive Kreis reaction, and this, in turn, is given during the period of induction of the fat oxidation, before active uptake of oxygen has commenced.

Grimes (1923) did not find the butter from ripened cream invariably deteriorated appreciably when stored six to seven months at — 6 deg. F. The cream was ripened to 0.5 to 0.61 per cent. acidity, and salted from 1.5 to 2.1 per cent. The good keeping quality of some of this butter is surprising. He concludes that "the occurrence of erratic decreases in score of butter made from ripened cream which rarely occurs when the cream is not ripened suggests that the deterioration of butter made from ripened cream is due to some as yet undetermined cause which may be aided in its action by the lactic acid produced during the ripening of the cream."

Hunziker (1927), in discussing cream ripening, states that "the danger of chemical deterioration of salted butter due to cream ripening may be not only minimized, but entirely avoided by so adjusting the per cent. acid in the cream, and the time and temperature of the ripening process as to ensure relatively low acidity, not to exceed 0.32 per cent. in the cream at churning time." With unsalted butter, the acidity may be 0.4 to 0.5 per cent. The figure 0.32 per cent. for salted butter is stressed throughout the book, and is considered a quite safe maximum. Although the subject is discussed at length, experimental results justifying such a comparatively high figure are not given.

Haglund and Waller (1922-1929) investigated the manufacture of butter under Swedish conditions. They confirmed the deleterious effect of high acidity on keeping quality. However, the acidities appear to be much higher than is generally considered desirable in this connexion, as they ranged up to 0.8 per cent., but the storage periods were comparatively short, namely, 20 days. They found that washing of the butter could not appreciably affect the acidity of the butter-fat or serum, and that the pH of the serum was mainly determined by the acidity of the cream.

White, Trimble, and Wilson (1929) report a complete series of experiments carried out with the object of determining just what is the most desirable acidity at which to churn cream where the butter is to be stored. Only salted butter was considered, the salt varying from 1.8 to 2.8 per cent.

In different series of experiments, the following methods of standardizing the acidity were used:—Addition of lactic culture and subsequent pasteurization; pasteurizing and then adding culture; pasteurizing followed by ripening; and ripening and neutralizing followed by pasteurizing. From their own results and examination of many commercial butters, the authors conclude that the quality of butter after storage is proportional to the acidity of the cream from which it was churned. When the butter was stored at 0 deg. F., the decrease in score, even after eight months, was very slight for acidities up to 0.31 per cent. The authors, however, state that there appears to be no advantage in making butter for storage from cream with an acidity as high as 0.31 per cent. Ripening cream with a lactic culture, even to low acidities, improves the score of the butter when fresh, but the improvement was usually lost during storage.

Some work has been published in which the hydrogen-ion concentration of the butter, rather than the titratable acidity of the cream, has been considered. Parfitt (1927) reports the results of the examination

of 186 samples of cold storage butters. The pH was found to increase during a storage of four months, but Parfitt does not correlate any decrease in score of the butter with the original pH. He found values ranging from 4.6 to 7.2. Cream neutralized to an acidity of 0.1 per cent. gave a butter of pH 7.2, to 0.2 per cent. a pH of 6.6, and to 0.3 per cent. a pH of 6.0. His determinations were made by making a 1 in 10 dilution of the melted butter and using this for a colorimetric estimation. The aqueous phase of the butter was thus diluted at least 1 in 60 before measurement, so, although the results may be comparative, little importance can be attached to the absolute values.

Guthrie and Sharp (1931), in an investigation of the effect of pH on churning time, made some interesting observations. They covered a wide range of acidities, far greater than would ever occur in practice. The fresh cream was adjusted to the desired pH by the addition of acid or alkali. The experimental butters were stored for seven months at 0 deg. F., and the results are shown diagrammatically thus:—

Flavour.

sharp acid cheesy — off flavours stale fishy — best flavours trifle stale — soapy stale alkaline

tallowy

pH 1 2 3 4 5 6 7 8 9 10 11 12 13 14

white — yellow — white

Colour.

The range pH 6 to 9 for best flavours is interesting. A cream of pH 8 to 9 would be very much over-neutralized, but no mention is made of alkaline flavours in the butter (compare the results of Barlow mentioned later). However, the authors point out that "it should be remembered that while the best flavour was found in the range from pH 6 to 9, the range of best flavour might be quite different if the cream had first been allowed to sour and had then been neutralized."

Hunziker, Cordes, and Nisson (1931) suggest the possibility of using pH as a test to indicate the suitability of butter for cold storage. They say that preliminary studies indicate a correlation between the pH of butter and its keeping quality. Their paper, however, is mainly devoted to the determination of pH of butter, and its relationship with the pH of cream and buttermilk. Nisson (1931) discusses the pH of butter and its relation to titratable acidity.

The papers so far discussed are confined to the keeping quality of butters churned from creams of varying acidities, but have not considered the neutralization of cream before churning when the cream has already developed excessive acidity. Practically all the authors agree that salted butter from high acid cream generally suffers in keeping quality, but this is not invariably the case. There appears to be some unknown factor which, in conjunction with high acidity, leads to deterioration in cold storage. When a large number of samples have been worked with and the results averaged, the loss in score during storage seems to be proportional in any increase in acidity over about 0.15 per cent. However, up to about 0.3 per cent., the loss appears to be negligible, and may be offset by improvement in the original score of

the butter. This upper limit of 0.3 per cent. appears to be well established by the papers quoted. Most of the papers deal only with salted butter, and there seems to be room for further work with unsalted butter. From the limited amount of published work, it would appear that this keeps better when made from ripened cream. Practical experience in Australia has not always confirmed this. A large amount of unsalted butter is now used in the manufacture of reconstituted milk and cream, and for this purpose, the flavour imparted by ripening cream is undesirable.

3. The Neutralization of Cream for Butter-making.

With the advent of the farm separator, and the consequent great increase in the supply of sour cream to the butter factory, the process of cream neutralization became common. At first, there was a tendency to regard neutralization as a form of adulteration, and some of the earlier papers are written with the object of justifying the practice, and showing the small effect it could have on the composition of the butter.

O'Callaghan (1915) gives a general discussion on the advantages and disadvantages of pasteurization and neutralization of cream under Australian conditions at that time. He finds it "advisable to neutralize to something below 0.2 per cent.", and states that neutralization with sodium bicarbonate greatly reduces food flavours by aeration. Ramsay (1915) discusses the possible reactions when sodium bicarbonate and calcium hydroxide are added to sour cream, and gives the results of analyses showing little difference in composition of butters made from neutralized and raw creams. McInnes and Ramsay (1918), and O'Callaghan and Ramsay (1918), describe the use of lime as a neutralizing agent. They also describe experiments where sodium peroxide was used as a neutralizer. It is not surprising that they found the butter had a "greasy taste, inclined to be tallowy." Ramsay (1920) reports the results of numerous laboratory and factory experiments on the neutralization of cream with sodium bicarbonate and lime. The results are interesting in showing the tremendous variations which can be obtained in factory work in the results of the neutralization. Complete neutralization with lime was never found, and very erratic results obtained with sodium bicarbonate. With the latter reagent, more complete neutralization was obtained with the flash system of pasteurization.

McInnes (1921) reports some experiments where a mixture of sodium bicarbonate and lime was used for neutralizing. Only about 60 per cent. of the theoretical effect was obtained, but the author does not comment on this result.

Valentine (1925) also, in a general article on neutralization with sodium bicarbonate, mentions some of the difficulties encountered in obtaining exact results. He says the addition of soda solution to the cream does not reduce the acidity more than 0.02 or 0.03 per cent. until heat is applied. After a certain amount of soda has been added to the cream, an extra quantity increases the acidity instead of reducing it. This is sometimes the case when neutralizing to a low degree of acidity, as is common in New Zealand (about 0.1 per cent.).

Barlow (1922) describes some interesting experiments on the effect of over-neutralizing the cream, and concludes that butter made from cream neutralized as low as 0.2 per cent. alkaline with sodium bicarbonate had no objectionable alkaline flavour, and that objectionable

alkaline flavours are due to faulty neutralization processes rather than excess of neutralizer. It is interesting to note that Parfitt (1927) found that butters criticized for having an alkaline flavour showed a pH on the acid side, averaging 5.35 on entering storage, and 6.38 on leaving store after four months. This increase during storage was considerably greater than that shown by any other type of butter. Evidently, some abnormality in ionic conditions in the butter serum was responsible for the "alkaline" flavour. These results and those of Guthrie and Sharp (1931) confirm Barlow's finding that a neutralizer flavour is not necessarily due to over-neutralizing.

Hunziker (1927) fixes 0.25 per cent. as the best figure to aim at in neutralization, so that there will be no danger of exceeding an acidity of 0.32 per cent. in the cream at churning time, the latter being the figure he considers the danger point when the keeping quality of the butter is considered. He discusses the various neutralizing agents that have been used, and states that the neutralizing action of the various soda neutralizers (carbonate, bicarbonate, sesquicarbonate, and proprietary mixtures) is exactly as calculated by chemical equations assuming a simple combination with lactic acid. With lime, he states that the neutralization obtained is approximately 80 per cent. of that calculated.

Davell (1929) made numerous small-scale experiments on cream neutralization in South Africa, where the practice does not appear to be general. He found no advantage from neutralizing creams which were below 0.4 per cent. acid, and even when the cream acidity was above 0.5 per cent. the improvement gained by neutralizing was not particularly marked. The acidity was reduced to 0.25 per cent. The results are interesting as showing a recent investigation where generally accepted practice was not upheld. However, it appears from the figures given that South African and Australian grading must be entirely different, and probably in many experiments, factors other than acidity were causing such serious deterioration that the effects of acidity were overshadowed.

Walts and Libbert (1930) experimented with eleven neutralizers, including sodium bicarbonate, sodium carbonate, four proprietary mixtures of these, and five lime-magnesia mixtures. A complete analysis is given of these. In all cases, the use of the neutralizer improved the score of the fresh butter, but in no case was there sufficient difference to justify a conclusion that any one particular neutralizer had any distinct advantage over any of the others so far as the flavour of the butter was concerned.

The majority of the work published, and the results obtained in countries where neutralization is a regular procedure, show that the keeping quality of the butter is undoubtedly enhanced by the practice. Most authors favour a neutralization to 0.2 to 0.25 per cent. acidity. There is no doubt, however, that many experienced butter-makers consider neutralization to a lower point to be desirable, and many factories have for years neutralized to about 0.1 per cent. acidity with good results. The majority of the papers published are American, and the authors have generally considered there is a danger of neutralizer flavour when a low acidity is adopted. When the original acidity is high, they recommend a smaller reduction than when low, to obviate the necessity of adding a comparatively large quantity of neutralizer.

However, very few results are quoted where the neutralization has been carried below 0.2 per cent. Barlow's results are interesting, as he made butter scoring as choicest when the cream had been made actually alkaline with sodium bicarbonate. It has been recommended to neutralize to 0.1 per cent. when the cream had an acidity of 0.35 per cent., and when of acidity over 0.5 per cent. to neutralize to 0.04 per cent. (Stenning, 1932), this being the reverse of the procedure common in America. However, experimental details of the advantages to be gained have not been given. There appears to be need of a complete and careful investigation to establish the most desirable acidity to which to neutralize the cream. Admittedly good butter can be made over a fairly wide range of acidities, but with the most desirable figure more firmly established the way would be open to the manufacture of a better standardized product.

The rate of reaction of the various neutralizing agents and the extent to which they reduce the acidity as compared with what might be expected, assuming a simple reaction with lactic acid, are questions which frequently arise. A few authors claim to have obtained the theoretical reduction with all of the common neutralizers, including lime, but when the subject has been carefully studied, quantitative results have never been obtained (see particularly Ramsay (1920) and Valentine (1925)).

4. Notes on the Theory of Cream Neutralization.

The dairy industry has adopted its own arbitrary method of expressing the "acidity" of its products. The acidity of milk and cream is always measured by titrating with a standard solution of sodium hydroxide, using phenolphthalein as an indicator, and in British and American countries the value so obtained is calculated as percentage lactic acid. While the use of phenolphthalein as indicator is most desirable, on account of the comparatively good end point obtained in the titration, it is unfortunate in that it has given rise to the too commonly held impression that a milk or cream showing a titratable acidity is necessarily "acid", and that the contents of "acid" is proportional to the figure obtained in the titration. This, of course, may not always be the case. The end point obtained with phenolphthalein in the titration of milk or cream occurs at about pH 8.5, i.e., distinctly alkaline. Milk and cream are well buffered solutions, and require an appreciable quantity of alkali to bring them from the true neutral point of pH7 to that of the phenolphthalein end point. Moreover, the acid-base system is so complex that different procedures in titration, such as dilution of the sample, lead to different results for the acidity. The phenolphthalein end point, although better than that given by other indicators, is not particularly sharp, and this, coupled with the nature of the fluid titrated, leads to difficulties in the exact control of acidity when low figures are desired.

A typical sour cream of titratable acidity 0.40 per cent. would have a pH of approximately 4.8. Its acidity before souring commenced would be about 0.11 per cent., and the lactic acid developed 0.29 per cent., assuming a simple lactic fermentation. At pH 4.8, the lactic acid (pK = 3.8) would be already 90 per cent. neutralized, so that greater part of the acidity measured in the titration is due to the other milk constituents present which buffer between pH 4.8 and pH 8.5.

These are the protein, chiefly casein, and the phosphates, citrates, and carbonic acid. The reactions are greatly influenced by the calcium and magnesium present, because of the low solubility of their phosphates and the slight dissociation of calcium citrate and caseinate.

When the acidity is measured by titrating with caustic soda, there is considerable fading at the end point, showing equilibrium is not established. This is due to the slow precipitation of tricalcium phosphate, as in the presence of calcium, phosphoric acid titrates to phenolphthalein as a tribasic acid and not as a dibasic acid as in simple solutions. When lime is used as a neutralizing agent, and the cream pasteurized, the tricalcium phosphate precipitation is more complete, and thus a lesser degree of neutralization is obtained than would have been expected from the caustic soda titration. Also Palmer and Richardson (1925) obtained the following results for the base binding power of casein :—

pH.	Gram equivalents of base-bound x 10^{-5}. per gram of casein.	
	NaOH.	$Ca(OH)_2$.
6	8	32
7	58	70
8	76	88

At pH 6, the higher quantity of calcium bound would correspond to about 0.05 per cent. of lactic acid in the titration, and at pH 7 to about 0.025 per cent. Thus, both the reaction with the phosphates and casein lead to a lesser neutralization when using lime than is to be expected from the soda titration.

When sodium bicarbonate is used as a neutralizer, it is obvious that the full reduction in acidity cannot be obtained before the cream is pasteurized. Sodium bicarbonate is "neutral" to phenolphthalein; so, in the cold, complete neutralization of the cream to this indicator could never be obtained. When the cream is pasteurized, carbon dioxide is lost, and the reaction approaches that obtained in the titration with sodium hydroxide. When the holding system of pasteurization is used, however, the loss of carbon dioxide is probably never complete, and the theoretical reduction in acidity is not obtained. The carbon dioxide is more completely driven off in flash pasteurization, so a lower acidity is found in the cream.

The carbon dioxide originally present in the cream behaves in the same way. If the sample which is titrated is not boiled, this carbon dioxide is estimated in the acidity, but after pasteurization of the main bulk of cream the carbon dioxide is driven off and the neutralization obtained may be greater than was calculated on. It has been suggested that other volatile acids produced by bacterial action sometimes occur, and in a similar way lead to errors in neutralization. This is hardly likely, however, as the only probable acids, besides being much less volatile than carbon dioxide, are considerably stronger and at the pH at which the cream is pasteurized would be held back as salts.

Even after pasteurization, it is possible that equilibrium is not fully established. It is well known that a slight flavour of neutralizer in freshly churned butter generally disappears after a few days. The

results of Parfitt (1927) are suggestive. He found that butters criticized for alkaline flavour were really acid when examined for pH, but that the pH increased during storage by slightly over one unit, whereas with other butters the increase was about 0.3 units.

From the above considerations, the erratic behaviour often noted in cream neutralization is not surprising.

5. Results of an Examination for Acidity of Victorian Butters.

The large variation in acidity of the butters now exported from Australia is shown by the following results, which were obtained on 70 samples of butter recently examined. These were obtained for a different investigation, by Messrs. Loftus Hills, and Scharp of the Victorian Department of Agriculture, and the author is indebted to these investigators for the opportunity of making the following measurements. With a few exceptions, the butters would all have been made from neutralized cream. The measurements were made on samples approximately one week after churning, and which had been kept in a chilled, but not frozen, state. The butters were all of first or choicest grade, and fell into the following groups:—

Grade for flavour.	No. of samples.	Per cent. of total number of samples.
39	3	4
40	8	12
41	24	35
42	27	39
43	7	10

For convenience, the results are grouped in the following table according to the pH range of the samples.

pH range of serum.	No. of samples.	Mean acidity of butter as per cent. lactic.	Mean acidity of serum as per cent. lactic.	Mean acid value of fat.	Mean peroxide in fat (c.c. $\frac{N}{500}$ $Na_2S_2O_3$ per gram of fat).	Mean grade for flavour maximum 50 points.
5·2–5·39	1	0·0500	0·250	0·63	1·1	40
5·4–5·59	0	..	..	..	..	..
5·6–5·79	2	0·0295	0·164	0·48	0·83	41·25
5·8–5·99	7	0·0249	0·104	0·57	0·79	41·14
6·0–6·19	6	0·0208	0·086	0·50	0·76	41·58
6·2–6·39	16	0·0154	0·073	0·60	0·87	41·54
6·4–6·59	10	0·0132	0·060	0·53	0·63	41·61
6·6–6·79	4	0·0108	0·039	..	0·66	41·25
6·8–6·99	7	0·0090	0·037	0·54	0·56	41·57
7·0–7·19	12	0·0073	0·023	0·56	0·60	41·54
7·2–7·39	3	0·0063	0·014	0·62	0·48	41·50
7·4–7·59	1	0·007	0·007	0·41	0·4	41.5
7·6–7·79	1	Alkaline	Alkaline	0·26	0·2	41
	70					

The following conclusions may be drawn from these results:—

1. The range of acidities is quite large. There is a distinct grouping of the samples about pH 6.3 and 7.1. Other evidence indicates that these figures correspond very approximately to acidities of 0.18 and 0.09 per cent. respectively in the cream.

2. There is a distinct correlation between the pH of the butter serum and titratable acidity of the butter and the serum. The pH of the butter serum was determined by the quinhydrone electrode on the undiluted serum, the butter acidity by the method of Nissen (1931) using $\frac{N}{50}$ sodium hydroxide, and the titratable acidity of the serum by titrating 10 cc. diluted to 100 cc. with $\frac{N}{50}$ sodium hydroxide.

3. There appears to be no correlation between the acid value of the fat and the acidity of the butter, except perhaps with the two most alkaline butters, but as only two samples were examined any conclusions would be doubtful. It is possible that the serum has been sufficiently alkaline to neutralize some of the fatty acid of the fat phase.

4. There is a correlation between the peroxide of the fat (Lea, 1931) and the acidity of the butter. If it can be established that this peroxide content is a true measure of the incipient oxidation of the fat and the onset of tallowiness, this result is important. The examination after three months' storage should give more conclusive results. The coefficient of correlation between the acidity and peroxide is — 0.51. As other factors, such as presence of copper and iron, and exposure to light, have been neglected, this correlation with acidity of the aqueous phase is interesting.

5. There appears to be no connexion between the grading of the various butters when fresh and their acidities. Except in the extreme instances where there were very few samples, choicest butter was found in all the groups. It is apparent that neutralization can be carried to quite a low degree without adversely affecting the flavour. In fact, from the results of these butters, acidity between say pH 5.6 and 7.4 seems to be one of the minor factors affecting the grade of the butter when fresh.

These results are included here to show the large variation in acidity obtained in good quality butter. If the most desirable acidity could be firmly established the way would be open for the manufacture of a more uniform product of possible better keeping quality.

6. References.

Barlow, 1922.—Alkaline flavour in butter. *Agric. Gaz. N.S.W.*, 33: 807.

Briggs, 1931.—The auto-oxidation of butter-fat. *J. Dairy Research*, 3: 70.

Cusick, 1920.—Phosphorus in butter. Cornell Univ. Ag. Expt. St., Memoir, 30.

Davell, 1929.—A study of the standardization of acid in cream for butter making under South African conditions. Transvaal Univ. Coll. Bull., 16.

Dyer, 1916.—Progressive oxidation of cold storage butter. *J. Agric. Res.*, 6: 927.

Grimes, 1923.—A study of the action of certain bacteria, yeasts, and moulds on the keeping quality of butter in cold storage. *J. Dairy Science*, 6: 427.

Guthrie and Sharp, 1931.—The effect of the hydrogen ion concentration on the churning time of cream. *J. Dairy Science*, **14**: 1.

Haglund and Walter, 1922-1929.—*Kgl. Landtbruks Akad Handl Tid.*, **61**: 435, **62**: 288. Medd. Centralanstalt försöksväsendet jordbruhs, Nos. 321 and 347.

Hunziker, 1927.—The Butter Industry, 2nd edition.

Hunziker and Hosman, 1917.—Tallowy butter—its cause and prevention. *J. Dairy Sci.*, **1**: 320.

Hunziker, Cordes, and Nisson, 1931.—Method for the hydrogen ion determination of butter. *J. Dairy Sci.*, **14**: 347.

Lea, 1931.—The effect of light in the oxidation of fat. *Proc. Royal Soc. B.*, **108**: 175.

MacInnes, 1921.—The neutralization of cream. *Agric. Gaz. N.S.W.*, **32**: 113.

MacInnes and Ramsay, 1918.—Neutralizing acidity in cream. *Agric. Gaz. N.S.W.*, **29**: 42.

Nissen, 1931.—The pH of butter, and its relation to titratable acidity. *Ind. and Eng. Chem. Analytical Edition*, **3**: 374.

O'Callaghan, 1907.—*Agric. Gaz. N.S.W.*, **18**: 223.

O'Callaghan, 1915.—Ibid., **26**: 277, 369.

O'Callaghan and Ramsay, 1918.—The partial neutralization of acidity in cream. Ibid., **29**: 115.

Palmer and Richardson, 1925.—3rd colloid symposium monograph, 1925, 112.

Parfitt, 1927.—The hydrogen ion concentration of cold storage butter. *World's Butter Review*, **1**: No. 3, 11.

Ramsay, 1915.—The neutralization of cream in butter manufacture. N.S.W. Dept. Agric. Sci. Bull., 16.

Ramsay, 1920.—Neutralization of cream. N.S.W. Dept. Agric. Sci. Bull., 17.

Rogers, 1909.—Fishy flavour in butter. U.S.D.A., Bur. An. Ind., Circ., 146.

Rogers and Gray, 1909.—The influence of acidity of cream on the flavour of butter. U.S.D.A., Bur. An. Ind., Bull. 114.

Rogers, Thompson, and Keithley, 1912.—The manufacture of butter for storage. U.S.D.A., Bur. An. Ind., Bull. 148.

Rogers, Berg, Potteiger and Davis, 1913.—Factors influencing the change in flavour of storage butter. U.S.D.A., Bur. An. Ind., Bull. 162.

Sommer and Smit, 1923.—The fishy flavour in butter. Wisconsin Agric. Expt. St., Bull. 57.

Stenning, 1932.—Queensland butter and cheese factory managers' conference, 1932.

Stiritz and Ruehe, 1925.—Some factors concerning the partial neutralization of cream for butter making. *J. Dairy Sci.*, **8**: 459.

Supplee, 1919.—The lecithin content of butter and its possible relationship to the fishy flavour. Cornell Univ. Agric. Expt. St., Memoir 29.

Valentine, 1925.—Acidity reduction in cream for butter making. *N.Z. J. Agric.*, **31**: 1.

Walts and Libbert, 1930.—The effect of various neutralizers on the flavour of butter. Arkansas Agric. Expt. St., Bull. 249.

White, Trimble, and Wilson, 1929.—Keeping quality of butter made from cream of various acidities. U.S.D.A. Tech. Bull., No. 159.

A Parasitological Field Trial on "Gundowringa," New South Wales, 1932.

By I. Clunies Ross, D.V.Sc. and N. P. Graham, B.V.Sc.†*

During 1931, field trials were initiated by the Division of Animal Health in order to investigate different aspects of the problems involved in controlling losses from internal parasites of sheep. This work forms part of the programme that is being undertaken by the Division under the Australian Pastoral Research Trust-Empire Marketing Board scheme (see this *Journal*, August, 1931, p. 134). The trials themselves are being carried out with the kind co-operation of Mr. D. E. Donkin, of "Meteor Downs", Springsure, Queensland; Mr. C. E. Prell, of "Gundowringa", New South Wales; and Mr. K. Brodribb, of "Frodsley", Tasmania, all of whom have very greatly facilitated the experiments by making the necessary experimental sheep and land available. The article that follows discusses the second year's work at "Gundowringa". The results of the first year's work at that station were published in a previous issue (February, 1932, p. 31).—Ed.

Summary.

1. Corriedale ewe lambs, grazed on improved pasture, both with and without anthelmintic treatment, and with and without rotation of pastures, at the rate of 2½ and 3 sheep per acre, respectively, made very much greater average gains in live weight, and produced from 1¾ to 2½ lb. more wool per head than sheep on natural pastures at the rate of one sheep per acre.

2. The average gain in live weight was 14 lb. per head and per acre on natural pasture; while on improved pasture, without rotation, it was 49 lb. per head and 122.5 lb. per acre, and on improved pastures, with rotation, it was 51 lb. per head and 153 lb. per acre.

3. Sheep on natural pasture produced, on an average, 9 lb. 2 oz. of wool per head and per acre, while on improved pasture up to 11 lb. 13 oz. per head and 35 lb. per acre were produced.

4. The sheep on improved pasture, and treated with an anthelmintic (carbon tetrachloride) at monthly intervals did not show any increase in body weight in comparison with sheep on similar pasture but not treated with an anthelmintic.

5. The sheep on improved pasture, treated with an anthelmintic (carbon tetrachloride), showed a material increase in the weight of fleece produced per head in comparison with untreated controls.

6. The effect of improved pastures on wool character was to produce a slight lowering in the count, but such wool was estimated to give as high, or higher, percentage clean scoured yield as that from natural pasture, and was of better staple length.

1. Introduction.

In 1931, the Council for Scientific and Industrial Research conducted a field trial on "Gundowringa" (20 miles north of Goulburn, New South Wales), to obtain evidence as to the effect of heavy stocking on improved pastures in increasing the risk of parasitic infestation. The results of this trial tended to show that, owing to the improved condition of sheep on such pastures, any increased risk of exposure to parasitism was more than compensated for by the greater resistance

* Officer-in-charge of the F. D. McMaster Animal Health Laboratory.

† Now an officer of the Australian Pastoral Research Trust, but formerly an officer of the Council allocated to the investigations being carried out under the Australian Pastoral Research Trust-Empire Marketing Board scheme.

of sheep to infestation. The trial about to be described was designed to offer confirmation to that of 1931, and had, in addition, the object of determining the effect of improved pasture in altering wool character.

Five groups of sheep were employed, as follows:—

1. *Lot* 1 comprised 50 sheep, grazed on natural pasture, at the rate of one sheep per acre. No treatment for parasites was given throughout. (Though this pasture had not been artificially improved, it was in part considerably better than the general natural pasture, owing to the fact that it had been a sheep-camp before the original property was subdivided).

2. *Lot* 2 comprised 50 sheep, grazed on improved pasture, at the rate of 2½ sheep per acre. No treatment for parasites was given. The "improved pastures" consisted of pasture that had been sown with subterranean clover and English meadow grasses, and fertilized every second year with 1 cwt. of superphosphate per acre.

3. *Lot* 3 was identical with Lot 2, except that all sheep were treated each month with 2 ccs. of carbon tetrachloride in 3 ccs. of liquid paraffin.

4. *Lot* 4 comprised 60 sheep, run on improved pastures, which were subdivided so that each unit was stocked for one month and then unstocked for three. The average stocking of the whole area was three sheep per acre.

5. *Lot* 5 was identical with Lot 4, except that all sheep received monthly treatment with carbon tetrachloride, as in the case of Lot 3.

Parasitic Conditions at the Beginning of the Trial.—Prior to the commencement of the trial, five sheep of the same age and type as those selected were examined *post-mortem* to determine the type of worm infestation present. It was found that the degree of infestation varied greatly in individual lambs, being quite heavy in certain small, undersized animals, but very light in those which were well grown. The species represented were *Haemonchus contortus* (the large stomach worm), *Ostertagia* spp., principally *O. circumcincta* (the brown hair worm, or medium stomach worm), *Trichostrongylus* spp. (the small stomach and intestinal worm), *Nematodirus filicollis* (the thin-necked intestinal worm), and in the large bowel *Chabertia ovina* and *Oesophagostomum venulosum.*

2. Conduct of the Trial.

The trial was begun on 8th January, 1932. The trial sheep were selected from Corriedale flock ewe lambs, 4 to 5 months old. The lambs were classed beforehand, and 270 selected as nearly equal in weight and condition as possible, any exceptionally large or small lambs being discarded. The weight of each lamb was recorded, and it was found that the average weight of all five lots was from 65 to 66 lb.

All sheep were weighed subsequently, at monthly intervals, and Lot 3 and Lot 5 were drenched with carbon tetrachloride. In order to observe, if possible, any marked change in the degree and type of parasitic infestation, faecal samples were cultured from five sheep in each group, the animals being chosen at random, at each monthly weighing.

In the hope of setting up initially some definite degree of infestation in all sheep with what is probably the most important species, *Haemonchus contortus*, each animal at the start of the trial was drenched with a dose of 100 *H. contortus* larvae by syringe.

The trial was terminated on 24th October, that is, after some nine and a half months. At this time, the sheep were shorn, individual fleece weights being recorded and the fleeces classed for quality and general character.

At the end of the trial, three sheep in each of Lots 1, 2, and 3, and five in Lot 4 were killed and examined *post-mortem* for parasites.

Climatic and General Conditions during the Trial.—The rainfall during the trial was as follows:—

	(Inches.)
January	—
February	.64
March	4.62
April	2.19
May	.83
June	3.22
July	2.68
August	3.08
September	1.59
October	1.86
Total	20.71

Owing to the lack of rain in January, and the low fall in February, it was not possible to maintain at the start the monthly rotation of Lots 4 and 5, as the available small dams of water gave out. In the heavily-stocked improved pastures, clovers, and grasses were eaten well down, but the sheep of these lots compared quite satisfactorily with the lot on the more lightly-stocked natural pasture.

Following good rains in March, all four improved pasture lots began to make rapid weight gains, which were continued throughout the very severe winter, during which very low temperatures, with occasional falls of snow and sleet were experienced up to late August. In contrast, Lot 1, on unimproved pasture, showed no material weight gains until September, these gains becoming marked in October.

Parasitic Infestation.—Faecal cultures on 8th February, one month after the trial began, gave a considerable proportion of *H. contortus* larvae in all groups.

Lot 1 showed 57 to 96 per cent. of *H. contortus.*
Lot 2 „ 74 to 98 „ „ „ „ „
Lot 3 „ 53 to 78 „ „ „ „ „
Lot 4 „ 40 to 99 „ „ „ „ „
Lot 5 „ 6 to 71 „ „ „ „ „

Faecal cultures, on 8th March, prior to the heavy rains of that month, showed—

Lot 1	showed	92 to 99	per cent. *H. contortus.*
Lot 2	„	82 to 100	„ „ „ „
Lot 3	„	0 to 39	„ „ „ „
Lot 4	„	78 to 92	„ „ „ „
Lot 5	„	0 to 2	„ „ „ „

It will be seen that two successive monthly treatments in Lots 3 and 5, under dry conditions, had effected a very striking reduction in the degree of infestation with *H. contortus.* Following the March and later rains, faecal specimens became diarrhoeic, and were less satisfactory to culture, but in all lots, whether treated or untreated, the degree of infestation with *H. contortus* diminished during the later winter months, only a minority of animals from which faeces were cultured showing such infestation. In September, the number of animals showing *H. contortus* again rose, but, owing to the unsatisfactory nature of cultures, it cannot be said definitely how the general degree of infestation in the several lots compared, but all appeared light.

3. Results of Trial.

(i) *Body Weight.*

At the conclusion of the trial in October, the average body weight of the five lots, and the average gain per head, and average gain in live weight per acre in the five lots, were as follows.—

Lot.	Average Weight in Pounds (October).	Average Gain Per Head in Pounds.	Average Gain in Live Weight Per Acre in Pounds.
1	80	14·5	14·5
2	114·5	49·0	122·5
3	115·5	49·0	122·5
4	117·5	51·0	153·0
5	116·5	51·0	153·0

It is seen that very striking increases occurred in all improved pasture lots, as compared with Lot 1, but that Lots 2, 3, 4, and 5 showed very little difference in their average weight gains. Dr. Carr Fraser has examined statistically the detailed figures from which the above table was drawn up, and finds no significant difference between any of these four lots. It is apparent (*a*) that Lot 2 and Lot 4, on improved pasture, untreated, compare more than favorably with Lot 1, and (*b*) that any increased risk of parasitism in the absence of treatment on heavily stocked improved pastures has been more than offset by the greatly improved nutrition of these animals. So far as the comparison of treated with untreated lots (Lots 2 and 3 and Lots 4 and 5) is concerned, medicinal treatment for parasites in no way influenced weight gains.

(ii) *Fleece Weights.*

The average fleece weights per head of each group, and fleece production per acre, as determined by weighing each fleece, were as follows:—

Lot.	Average Fleece Weight Per Head.	Fleece Weight Per Acre.
1	9 lb. 2 oz.	9 lb. 2 oz.
2	11 lb. 3 oz.	27 lb. 3 oz.
3	11 lb. 13 oz.	29 lb. 8 oz.
4	10 lb. 14 oz.	32 lb. 10 oz.
5	11 lb. 10 oz.	34 lb. 14 oz.

The figures for fleece production represent eleven months' wool growth, the lambs having been shorn previously on 21st November, 1931, while for only nine and a half months during the actual trial had they been grazed under varying conditions. It is seen that all four improved pasture lots produced more fleece than the natural pasture group. So far as the effect of medicinal treatment is concerned, Lot 2 is comparable with Lot 3, and Lot 4 with Lot 5. Dr. Carr Fraser has found that the probability of the difference in production of Lot 2 and Lot 3 being due to chance is 1 in 80, this being almost significant, while the difference between Lot 4 and Lot 5 is undoubtedly significant. It is seen, therefore, that though the body weights of these groups did not differ significantly, medicinal treatment was able to bring about a significant increase in wool production, even though parasitic infestation at no time was really heavy, while it is probable that *H. contortus* was the only parasite the incidence of which was markedly affected by the treatment.

(iii) *Quality of Wool.*

So far as the quality of wool in the several lots was concerned, attention was directed towards the elucidation of the influence of pasture improvement in affecting wool character, particularly its strength (count) and condition. It is generally held that grazing sheep on improved pasture markedly strengthens wool, and also increases the amount of condition carried, thus lessening its clean scoured yield, and lowering its value. It was also necessary to see whether repeated (10) monthly drenchings with carbon tetrachloride had had any harmful effect on the fleece, it having been maintained in some instances that such drenching leads to harshness of the fleece.

Count.—The percentages of fleeces classed as from 56's to super 60's in each lot are given below. As set out, 58/60's and 60's are grouped together, as are 60+ and 64, of the latter of which very few occurred.

Lot.	% 56's or less.	% 58.	% 58/60 and 60.	Super. 60 and 64.
1	2	10	57	31
2	..	27	56	17
3	7	20	53	20
4	2	21	58	19
5	4	27	54	15

It is seen that, in each lot, the bulk of fleeces fell in the 58/60, 60's group. In Lot 1 there was a higher percentage of super 60 and 64's, while in the improved pasture lots there was a correspondingly higher proportion of 58's. There was, however, very much less difference in count in the improved compared with unimproved lots than is popularly supposed to occur. It has to be remembered, moreover, that a well and evenly grown 58's wool may have a higher spinning value than a poorly grown 60's, and this point must also be considered in evaluating the effects of improved pastures on wool character.

Staple Length.—Considerable difference in staple length was found when Lot 1 was compared with any of the improved pasture lots. In Lot 1, the bulk of the fleeces were 3 inches to $3\frac{1}{2}$ inches in length, while in all improved pasture groups the majority of fleeces were of 4-inch length or over.

Estimated Clean Scoured Yield.—Clean scoured yield was estimated by a skilled wool classer, after careful examination of each fleece. Contrary to popular opinion, there were considered to be at least as many high-yielding fleeces in each improved pasture lot as on the unimproved lot. The majority of fleeces in all lots fall within a group estimated to yield from 57 to 58 per cent. of scoured wool, and actually in each of Lots 2, 3, 4, and 5 there was a slightly greater proportion of higher yielding wool (59 to 60 per cent. or over) than there was in Lot 1.

Influence of Repeated Drenching.—There was no evidence that repeated drenching with carbon tetrachloride had in any way affected wool character adversely. The wool in Lots 3 and 5 was as clean, bright, and attractive to handle as that of Lots 2 and 4.

4. Parasitic Infestation found on Post-mortem Examination at the End of the Trial.

From faecal cultures, it was found that some degree of infestation with *H. contortus* existed in all groups. It was evident, therefore, that monthly drenching in Lots 3 and 5 had failed to eradicate this species, even though in Lot 5 rotation over pastures rested for three months between successive stockings had been practised. As has been mentioned, several animals in Lots 1, 2, 3, and 4 were killed and examined *post-mortem*. Only very light mixed infestations were found in any animal on improved pasture (Lots 2, 3, and 4), but in sheep from Lot 1, up to 800 adult *H. contortus* were found.

5. Conclusion.

Under conditions met with in this trial, any increased risk of parasitic infestation on heavily stocked improved pastures is more than compensated for by the improved health of sheep, as shown by greatly increased wool and mutton production. Nevertheless, anthelmintic treatment of sheep on improved pasture may lead to material increases in wool production, when compared with similar groups not so treated. While the influence of pasture on wool character leads to a slight lowering in count, it does not necessarily lead to the production of wool having a lower estimated clean scoured yield.

The Physiological Relations between Tillers of a Wheat Plant.

*By H. Fairfield Smith, B.Sc., M.S.A.**

The primary object of the plant breeder, and the economic incentive behind the plant geneticist's investigations is the production of better yielding varieties of plants. In the course of most plant breeding investigations, it is thus necessary to measure yield with as much accuracy as possible. In so far as the Council's genetical studies of wheat are concerned, it was necessary to determine whether the whole plant or a tiller should be regarded as the unit on which to base investigations. Work to determine that point has now been carried out, and is discussed in the report that follows. It indicates that tillers are not completely independent units, and that it is necessary to deal with the whole plant when considering the yield of wheat.—Ed.

Summary.

Translocation between culms of a wheat plant after the flowering period is possible, but is probably unimportant in the normal plant. Evidence for this statement was obtained by restricting the photosynthetic ability of some culms by defoliating them and darkening their stems. If the attached tillers had their ears cut off, they contributed to the production of grain in the defoliated culms; but if they had ears of their own to fill, then their contribution to a defoliated companion was not appreciable. (Sections 1 and 2.)

Water from the roots is distributed evenly between all tillers of a wheat plant irrespective of individual tillers to which roots are directly attached. (Section 3.)

Excision of side tillers (including some ear-bearing tillers) increased the weight of grains on main culms by 5 per cent. The interpretation is, however, debatable, and it cannot be taken to prove that side tillers are harmful. (Section 4.)

Leaf blades, stem, and ear of a culm each contribute about equally to the dry matter in the grain. (Section 1.)

Engledow and Wadham, in their investigation of yield in barley (6), surmised from more or less circumstantial evidence that tillers may be independent units after the early stages. Dungan (5) has shown that, in the maize plant, suckers can contribute to the nourishment of the main stem when the latter has been stripped of its leaves. The experiments reported in this paper were undertaken to obtain, for wheat, more direct evidence than has yet been available on the possibility of inter-tiller translocation during the later stages of growth. They formed part of an investigation on methods for the analysis of yield in wheat. They indicate that tillers are not completely independent units, and that the plant should be regarded as an individual entity.

1. Experiments of 1930.

The experiment consisted of observing the effect on yield of interfering with the photosynthetic ability of some culms†.

* Junior Plant Geneticist, Division of Plant Industry, C.S.I.R.

† Engledow and Wadham (6) use the term "tillers" to describe all side shoots from the primary stem. The primary stem is thus not regarded as a tiller. Accepting this usage of the word "tiller," the American word "culm" has been used in this paper to describe ear-bearing stems, including the primary stem. The two terms thus overlap but the primary stem is not classed as a tiller, and tillers which fail to bear ears are not classed as culms.

Grain of Canimbla, a late freely tillering variety of wheat, was carefully selected by hand and sown by dibbing to a uniform depth. Seeds were placed 4 inches apart in four rows spaced successively 1 foot, 3 feet, and 1 foot apart. There were thus two pairs of rows with pathways on both sides of each pair. Each plant had between 15 and 33 culms. Near flowering time, five groups of eight healthy neighbouring plants were selected. The eight plants of each group were numbered at random, and treated according to the number thus assigned. Three extra treatments (given in the last column of Table I.) were applied to only one plant each. Flowering of the main ears began on 9th November, and the operations were performed from 10th to 12th November.

After harvest, a few ears which had been damaged by birds, and small ears having less than 13 fertile spikelets were discarded. The remaining ears varied in size from 13 to 26 fertile spikelets per ear, and every plant had ears well distributed over this range. Measurements indicated in the Appendix were recorded for each culm separately.

Ability to produce carbohydrates was reduced both by defoliation (cutting off leaf blades) and by excluding light from the stems. The latter effect was obtained by using tubes made of brown paper. Three layers of paper were used to obtain an almost opaque cover, but it was not quite opaque in full sunlight. The covers were subject to two other defects in that the upper edges of the tubes were only loosely fastened with paper clips to allow unrestricted growth of the culms so some light would be admitted at this point, and each tube enclosed several culms of different heights, so that some had a considerable length of stem above the enclosing tube, while others had the ear still partially below the rim.

Attention was concentrated on defoliated and darkened culms, but other treatments were also included. Treatments fall into three main groups:—

A.—Plants in which all culms were similarly treated. (These plants serve as controls for groups B and C).

B.—About one-fifth of the number of culms of a plant were defoliated, or defoliated and darkened; the other culms were untouched.

C.—Similar to B, but the ears were cut off the other culms.

The various treatments and the relation between them is indicated in Table I.

In order to reduce the error of estimates of yield per ear, use was made of the regression of yield characters on the number of fertile spikelets, a character determined before, and unaffected by, treatments (*vide* Appendix). Twenty fertile spikelets were selected as a suitable size of ear near the centre of the range to be used as a standard size. Weight per grain, and number of grains per ear, were estimated for an ear of this size for each treatment. Differences in numbers of grains per ear between groups A, B, and C were negligible. Weights per grain are given in Table I.

In Table I are also shown the differences in weight per grain between controls, in which the normal yield has been, presumably, reduced equally in all culms, and corresponding culms in other plants which may show the benefit of any possible translocation from attached tillers. Although considered individually only one of these differences approaches significance, the consistency over all groups suggest that a conclusion may be drawn with some confidence. It is at least strongly suggested that if a tiller has no ear of its own to fill, then material may be translocated from it to attached culms whose productive powers have been decreased. But if a tiller has an ear of its own, it fails to supply any appreciable quantity of foodstuffs to needy neighbours. Even under the former condition translocation, although possible, appears to be extremely inefficient. Earless culms were over three times as numerous as the defoliated and darkened culms, but they enabled these to regain only less than half of the reduction in grain size caused by the treatment.

TABLE I.—AVERAGE WEIGHT (MGM.) PER GRAIN PER STANDARD EAR (HAVING 20 FERTILE SPIKELETS) FOR GROUPS OF CULMS AS INDICATED.

—	Replicated five times.				Only one plant each.
	Normal.	Defoliated, stems light.	Leaves and stems darkened.	Defoliated, stems darkened.	Leaves, stems and ears all darkened.
A—All culms of a plant treated as indicated in the upper margin, (serving as controls for groups B and C)	49·1	30·2	24·1	20·6	10·2
B—Four to six culms of a plant treated as indicated, the other culms left normal	*35·0	†30·0	..	‡21·7	§9·2
C—Four to six culms of a plant treated as indicated, the ears cut off other culms ..	..	†36·5	..	‡29·4	§14·2
Difference, B—A ..	−5·1±3·3	−0·2	..	1·1±3·2	−1·0
" C—A ..	..	6·3	..	‖8·8±3·2	4·0

* Estimated for the mean of all normal tillers of plants in group B—two plants in each block.

† Estimated from two or three culms in one plant of each block. The same plant had also two or three culms with stems darkened which contribute to data in column 4.

‡ Estimated from four–six culms in one plant in each block, plus two–three culms in a second plant as noted in the preceding footnote.

§ Estimated from three culms.

‖ For this difference $t = 2.8$, $n = 8$, $P = .03$. Other differences between controls and groups B and C are not significant.

GENERAL NOTE.—All plants have a total of between 15 and 33 culms.

TABLE II.—WEIGHTS OF GRAIN PER STANDARD EAR FOR PLANTS OF GROUP A.

1. Normal	1·90 grm.
2. Defoliated	1·35 "
3. With leaves, leaves and stems darkened	·99 "
4. Defoliated, stems darkened	·79 "
5. Leaves, stems and ears all darkened	·34 "
(Standard error of a difference	·28)

For the plants of group A the total grain weights per ear of 20 fertile spikelets are given in Table II. They indicate that the ear (glumes, awns, &c.), the stem, and the leaf blades each contributed about one-third of the normal weight of the grain. In view of the defects of the covers used and since the grain may be expected to extract the maximum possible amount of carbohydrate from the glumes, &c., when other sources of supply—leaves and stems—are put out of action, treatment 4 ought to over-estimate the amount normally contributed by the ear. It appears, therefore, that under ordinary conditions the ear probably contributes less than 40 per cent. ($0.79/1.90 = 41\%$) of the material in the grain. It may be of interest to compare this with the finding of Boonstra (3) that almost the whole of the carbohydrate in the grain is contributed by the glumes.

2. Experiments of 1931.

Similar experiments, but using only abscission operations, were conducted in 1931. Canimbla was again used. The plan of seeding was similar to that of 1930, except that only 6 inches separated a pair of rows. Five adjacent plants were taken to form a block. To each plant one of five operations was assigned at random. There were nine blocks. Measurements of yield were taken on only the two largest culms of each plant which were marked with wool when operations were performed. In addition to the more usual measurements of yield, the weight of 10 grains, obtained by taking the two basal grains from the five largest spikelets of each ear, was also observed. It was thought that this might be a more accurate measure of grain size than is the average weight per grain usually employed, although there is little difference between the two measures. The correlation between them is $r = .956$ and the ten selected grains were about 16 per cent. heavier than the average of all grains per ear. The weight of the 20 grains thus obtained from each plant was used as the measure of weight per grain per plant.

Owing to the use of only the two largest ears per plant, variation in size of ear was small and correlation between grain weight and number of spikelets was insignificant. Consequently, in this experiment there is no gain obtainable by estimating values for a standard size of ear; simple averages per treatment are equally efficient.

The five treatments used, and the mean weight of 20 grains for each treatment are shown in Table III. From the analysis of variance (Table IV.), it appears that the differences between treatments are not significant. The experiment is nevertheless reported here because such differences as exist agree with the results of 1930.

The effect of cutting off leaves may be estimated from twice as many differences as are available for a comparison between any two single treatments. It may be estimated from treatments 1 and 2 versus 3 and 5. This difference is significant. It is 20.6 ± 8.0 cgms., $t = 2.6$, $n = 39$ (Table IV.), $P < .02 > .01$. The decrease is 22.5 per cent. and it agrees closely with the decrease of 25 per cent. between treatments 1 and 2 in 1930.

A further five pairs of plants had the leaves cut off the two largest culms. As to the remaining tillers, they were cut entirely off one plant of each pair, whereas in the other of each pair they had their ears cut

off. Corresponding ears were compared in pairs by Student's method, with respect to the weight of 10 grains. One ear was damaged leaving 9 pairs. The culms accompanied by earless tillers gave heavier grain than the solitary ones. The difference was 12 cgms., $\pm$ 3.2, $t = 3.8$, $n = 8$, $P = .01$. This therefore corroborates the experiments of 1930 in showing that under special circumstances translocation between tillers and culms is possible.

TABLE III.—TREATMENTS AND GRAIN WEIGHTS FOR 1931 EXPERIMENT.

Treatment.		Mean Weight of 20 Grains (centigrams).	Mean No. of Grains from Two Ears.
Two Largest Culms.	Remaining Tillers.		
Normal	Normal	94·2	83
Normal	Cut off at the base ..	89·2	91
Leaves excised ..	Normal	72·9	86
Leaves excised ..	Ears cut off	73·8	76
Leaves excised ..	Cut off at the base ..	69·0	84
Standard error	.. .. ..	7·8	6·7

TABLE IV.—ANALYSIS OF VARIANCE FOR 1931 EXPERIMENT.

Due to—	Degrees of Freedom.	Sum of Squares.	Mean Square.	$\log_e$
Treatment	4	4,419·2	1,104·8	7·007
Blocks	8	2,068·2	258·5	
Remainder	31	19,545·6	630·5	
Blocks + Remainder	39	21,613·8	554·2	6·317
Total	43*	26,033·0		

$z = \cdot 345 \quad P > \cdot 05$

* One plant in Treatment 1 was seriously diseased and had to be discarded. Attributes for this plant were estimated by Allan and Wishart's formula (1). One degree of freedom was thus lost, making the total number 43 in place of 44, which would be expected for 45 plants.

3. Lateral Translocation of Water from Roots.

At the beginning of their flowering period in 1930, some further experiments on translocation from the roots were performed on plants of Canimbla growing at 4 x 12-inch spacing. By spraying with water from a hose, the earth was washed away from the roots on one side of six plants. About one-third of the roots of each were then severed by cutting. Waxed paper was inserted below the cut surfaces to prevent development of new roots.

After harvest, it was not possible to identify with certainty all the roots growing from each individual tiller, but the tillers of each plant could be divided into three groups:—(1) those on one side whose roots

had not been touched, (2) those on the other side practically all of whose roots had been cut, and (3) a group in the middle whose status could not be determined with certainty. By a similar method of analysis to that described for the 1930 experiment, it was found that the weights of grain per ear of twenty fertile spikelets were as follow:—

Control	.. ..	$1.93 \pm .033$ gms.
Experimental plants. Culms with roots remaining		$1.47 \pm .054$,,
,, ,, ,, ,, ,, cut		$1.46 \pm .073$,,

Cutting a third of the roots affected the yield from the whole plant; but culms whose roots had been severed were not affected more than were culms whose roots remained attached. It therefore seems that supplies from the roots may be distributed to any culms of the plant, irrespective of those to which the supplying roots are directly attached.

Richardson and Trumble (8), and Burd (4) have shown that under normal conditions most of the minerals absorbed by barley are taken up during the early stages of growth; Gericke (7) found that to enable wheat to produce its full yield, only water, with perhaps traces of iron and nitrogen, is required during the later stages of growth. For trees, Auchter (2) found that water can be supplied by any root to any part of the plant, but that minerals tend to remain on the same side of the tree as that on which they are absorbed. The above demonstration of lateral distribution from the roots of a wheat plant may therefore be applied only to water. The distribution of mineral nutrients requires separate demonstration.

4. Effect of Removing Side Tillers on the Yield of Main Culms.

Having shown that translocation between culms is possible, can we obtain any evidence as to whether or not side tillers which fail to bear ears may be only parasitic on, or competitors against, the main culms, without service rendered in return? Dungan (5), in reviewing the literature, indicates that removing non-earbearing suckers from maize plants is detrimental to their yield.

A bed which had been sown with Canimbla wheat at 6 x 2-inch spacing was divided into eight plots. Where different treatments were adjacent a 6-inch border was discarded. The plots were arranged and numbered as follows:—

1	2	3	4
5	6	7	8

Plots 1 to 4 were 2 x 4 feet, and plots 5 to 8 were 2 x 2 feet, but records have not been collected for all the plants in each plot. Plots 5 to 8, which were lower than plots 1 to 4 owing to the slope of the ground, were irrigated weekly. Flowering began about 26th October. On 19th October, in plots 2, 3, 5, and 8 tillers were cut off to leave only two main culms. Plants which were not large enough to produce two good size ears had only one culm left. In addition to very small side tillers which were from 1 to 6 in number and which had already withered, there was cut off from each plant from 0 to 5 tillers of a size which would have died later, and 0 to 3 tillers large enough to have formed ears.

After harvest, the weight of 6 grains per ear, 2 basal grains from each of the three largest spikelets, was obtained for two ears per plant (or for some plants as indicated above, one ear). Evidence that the plots were similar and evenly matched before operations were begun is given by the means and standard deviations of the numbers of fertile spikelets per ear. (Table V.) Since there was no correlation between grain weight and number of spikelets, grain weight has been treated as an independent character. Within each plot, the frequency distribution of grain weight was approximately normal between 24 and 36 cgms., but extended below this range more or less erratically down to six cgms. The light grains were due to plants attacked by foot-rot. Since, however, it is difficult to fix a border line between diseased and healthy plants, it is difficult to decide what ones should be discarded, but if all are kept, these light grains seriously upset the values of the means. It was therefore decided to use the modes as the best estimate of grain weight for each plot. Modes were estimated by the formula

$$Mo = x_m - \tfrac{1}{2} \triangle x + \frac{f_{m+1}}{f_{m-1} + f_{m+1}} \triangle x$$

and are shown in Table V. An analysis of variance for a comparison between plots is given in Table VI., whence it appears that the grains from the treated plots are slightly, but significantly, heavier than the grains from the controls.

Analysis of the data was carried further by classifying the treated plants according to the number of excised tillers which might have borne ears. For this purpose, it was deemed permissible—since previous examination had shown that differences between corresponding plots were negligible—to treat all plant records from the four treated plots as a homogeneous sample.

Four rows (no two adjacent) had to be discarded because after harvest the plants could not be connected plant for plant with the field notes. By coincidence, these rows contained the worst of the diseased plants so that the distribution of the remainder was close enough to the normal distribution to permit the use of means. The mean grain weight for untreated plants neglecting all values less than 20 cgms., was calculated to provide a comparable value for the controls. The mean grain weights per 6 grains for each class were as follow:—

(1) Controls (discarding weights per 6 grains less than 20 cgms.) ..	29.38 ± .34 cgms.
(2) Only non-earbearing tillers excised..	30.01 ± .39 „
(3) One earbearing tiller excised ..	30.91 ± .27 „
(4) Two or three earbearing tillers excised	30.97 ± .27 „

Of the differences between treated groups, that between classes (2) and (4) just approaches significance. The difference is .96 ± .47. ($P = .04$).

These results cannot however be accepted as proof that side tillers are harmful to the production of grain on the main culms. A possible explanation of the differences observed is that during the hot days of

summer the root systems of the plants whose culm number had been reduced to two were better able to deal with demands upon them for water. Since it has been shown that water supply is not restricted to tillers from which the supplying roots have grown, and since the extra tillers contributed to the formation of roots before they were taken away, there is no indication that the gain could have been obtained if the plants never had the excised tillers. It seems possible that tillers

Table V.—Mean and Standard Deviation of Number of Fertile Spikelets per Ear, and Modes of Weights of 6 Grains per Ear for Each Plot.

Plot No.	Number of Fertile Spikelets.		Modal Weight of 6 Grains (centigrams).	No. of Ears Examined.
	Mean.	Standard Deviation.		
1	14·4	2·5	30·0	106
2	14·1	2·1	30·8	107
3	14·2	2·4	30·9	99
4	14·3	2·3	29·6	86
5	13·2	2·0	31·0	51
6	13·5	2·1	29·0	61
7	13·6	2·2	28·7	51
8	14·4	2·2	30·9	41

Table VI.—Analysis of Variance for the Modal Values of Grain Weight in all Plots.

Due to—	Degrees of Freedom.	Sum of Squares.	Mean Square.	*z*.	*P*.
Between treatments ..	1	4·961	3·904	1·794	< ·01
Between blocks*	1	·361	1·284	·484	> ·05
Remainder	5	·687	·315		
Total	7	6·009	..		..

* Includes effect (if any) of irrigation.

Mean of treated plots = 30.9 cgms.
„ „ control „ = 29.3 „
Difference = 1.6 ± 0.4.

which die about flowering time, if they have contributed to root growth, may not have lived in vain, but this possibility may not be assumed without further proof. In any case, this form of service will only be applicable when soil water is adequate and when transpiration is great enough to tax the supplying power of the roots; for example under conditions of irrigation or in hot countries when, as in Eastern Australia

in 1931, rainfall during the grain filling period is plentiful. It cannot be expected to apply when soil water is limiting, or where, as in England, evaporation is low.

5. Literature Cited.

(1) Allan, F. E., and Wishart, J.—A method of estimating the yield of a missing plot in a field in experimental work. *J. Agric. Sci.*, 20: 399-406, 1930.

(2) Auchter, E. C.—Is there normally a cross transfer of foods, water, and mineral nutrients in woody plants? Maryland Agric. Expt. St., Bull. 257: 33-60 (1923).

(3) Boonstra, A. E. H. R.—Plant breeding and plant physiology.—Der Züchter 3: 345-352 (1931) Quoted from Imper. Bur. Pl. Gen., Pl. Breeding Abs. 2, No. 207.

(4) Burd, J. S.—Rate of absorption of soil constituents at successive stages of plant growth.—*J. Agric. Res.* 18: 51-72 (1919).

(5) Dungan, G. H.—An indication that corn tillers may nourish the main stalk under some conditions.—*J. Amer. Soc. Agron.* 23: 662-670 (1931).

(6) Engledow, F. L., and Wadham, S. M.—Investigations on yield in the cereals I, Appendix III.—*J. Agric. Sci.*, 14: 80-85 (1924).

(7) Gericke, W. F.—Salt requirement of wheat at different growth phases.—*Bot. Gaz.* 80: 410-425 (1925).

(8) Richardson, A. E. V., and Trumble, H. C.—Transpiration ratios of crops in Adelaide district.—Dept. Agric. South Australia, Bull. 226 (1929).

Appendix I.—The Methods of Calculation used in Section 1.

Underlying the plan of the 1930 experiment, there lay an intention to compare the yields of the treated and control culms by comparison of the regressions of yield on some stable culm character which was unlikely to be effected by the treatments. A secondary object of the experiment was to test the practicability of using such a method in yield experiments. Since grain weight per ear varies with the size of culm, it is unsatisfactory to compare directly culms of different sizes. A comparison of regressions of grain weight on size of ear is equivalent to comparing average grain weights for corresponding ear sizes without the labour of matching ear for ear. Characters considered as possible to indicate culms of corresponding size were, number of fertile spikelets, number of sterile spikelets, total number of spikelets, length of ear, weight of chaff plus rachis, weight of straw, and length of straw. Numbers of spikelets are probably least likely to be affected by the treatments, and it was found that number of fertile spikelets was more closely correlated with grain yield than any other of the characters enumerated. The following correlations to this character were obtained for 70 culms from four normal plants.

Between weight of grain per ear and number of fertile spikelets .. .. $r = .91$

Between number of grains per ear and number of fertile spikelets .. .. = .89

Between average weight per grain per ear and number of fertile spikelets .. .. .. = .61

For analytical yield studies, it seems advisable to consider separately the components of yield, number of grains, and weight per grain. In the following discussion, only weight per grain is considered. Number of grains was similarly examined.

Let number of fertile spikelets be designated F, and let weight per grain be g.

TABLE VII.—ANALYSIS OF VARIANCE FOR FOUR NORMAL PLANTS.

Due to—	Degrees of Freedom.	Sum of Squares.	Mean Square.
Variance about regression of g on F within single plants	51	179·8	3·53
Variance between values of g for $F = 20$ in each plant	3	97·2	32·4

TABLE VIII.—ANALYSIS OF VARIANCE FOR FIVE PLANTS HAVING ALL CULMS DEFOLIATED AND STEMS DARKENED.

Due to (see Table I.)—	Degrees of Freedom.	Sum of Squares.	Mean Square.
Within plants	62	214·9	3.46
Between plants	4	104·1	26·0

Preliminary observation of normal plants had suggested that the relation between g and F per culm might be the same for all plants in a small plot, but critical statistical examination—Tables VII. and VIII. —showed that this was not the case. A sample formed of several tillers from several plants was not homogeneous. Therefore to obtain valid estimates of error for comparisons between plants, it was necessary to calculate a separate regression for each plant and thence obtain a single measure per treatment per block. Since different treatments had considerably different numbers of culms from which records were obtained

(*vide* Table I.), an average error for different treatments could only be obtained for treatments with similar numbers of culms. Consequently, degrees of freedom available for estimating errors were few. The procedure is tedious, and where differences were obviously insignificant —owing either to the smallness of a difference or to the small number of observations concerned—or where an estimate of error was unimportant, the grain weight was estimated from bulked data in which each plant had equal weight.

In view of the differences between plants indicated by Tables VII. and VIII., the suggested method, using regressions, is not convenient for dealing with a few large plants as in the present case. The experiment of 1931 indicates that if a large number of plants with only a few ears from each be used, then ears may be readily selected which are so similar that the correlation of characters within them is not worth considering for the purpose of increasing the accuracy of the means.

Explanation of "analysis of variance," and of the statistics z, t, n, and P may be found in "Statistical Methods for Research Workers" by R. A. Fisher.

A Note on Some Aspects of Anti-Bacterial Immunity.

By L. B. Bull, D.V.Sc.

For some time past, the Council's Division of Animal Health has been giving a considerable amount of attention to determinations of the precise causes (generally a determination of the species of bacillus concerned) of a number of previously obscure diseases of Australian livestock. The recent work on black disease of sheep, braxy-like disease in Western Australia, pulpy kidney, &c., are instances of this work. Generally, once the cause of a disease is known, a means of control can be suggested. At times, however, such control methods, and methods developed for other diseases the causes of which have long been known, are not particularly simple or economic. Nevertheless, the rather rapid advances in the field of immunology that have been made during recent years are full of promise in connexion with the development of disease control methods in general. Dr. L. B. Bull, Director of the Government Laboratory of Bacteriology and Pathology, Adelaide Hospital, has recently prepared a brief statement dealing with various aspects of such immunological work in connexion with a matter which he has been discussing with the Chief of the Council's Division of Animal Health, Dr. J. A. Gilruth. That statement, however, is of general interest, and Dr. Bull has now kindly agreed to having it printed below.—Ed.

In this note, we will not consider the filterable viruses nor the immunity produced following recovery from their invasion of the animal body.

Pasteur was the first to employ bacteria for the purpose of producing resistance to natural infection. He introduced the method of employing attenuated cultures for this purpose. The basis of the procedure was the belief that any particular bacterium growing in the animal body exhausts the pabulum for that particular organism, and so the body is protected against further invasion. He therefore used live, although attenuated, cultures of the organisms, and injected them under the skin of the animal.

Although very great success was obtained by Pasteur and others following his methods, the employment of living cultures has usually given rise to some loss of life, and in some instances to very great loss of life. The fixity of the attenuation could not always be relied upon, and if attenuation were carried too far the resistance produced might be too slight to be effective against natural infection. Further, the use of living cultures is associated with a risk of disseminating infection. Although the methods have been employed very largely for the protection of the domesticated animals, they have not been used to any extent to protect human beings, and there has been an increasing tendency to depart from the use of living cultures in veterinary work. At the same time, it is generally recognized that the living antigen is superior in most instances. There is an exception to this, however, in the case of infections due to bacteria producing a diffusible toxin. Many bacteria which were unsuspected as toxin-producers have, of recent years, been shown to produce powerful toxins, and these can also be produced under artificial conditions if proper methods are used.

Immunity to infection by these toxin-producers has been shown to be almost, if not entirely, an antitoxic immunity, and very much better results are to be obtained by artificial inoculation with toxin or modified toxin than by attenuated cultures of these organisms. This fact is best illustrated in the infections due to many of the anaerobic bacilli.

The advance along these lines is very important, and it illustrates that we can, by artificial means, produce results that are greatly superior to those obtained under natural conditions. It is held by many that if immunity does not result from natural infection then we are not justified in hoping to produce an immunity by artificial means. The degree of immunity that can be produced artificially by the use of modified toxins is much greater than occurs under natural conditions. This result has been rendered possible by a more thorough understanding of the factors responsible for the production of disease and the antigenic make-up of bacteria and their products.

Nowadays, we believe that Pasteur was wrong in holding that exhaustion of a special pabulum in the animal body was necessary for the production of immunity. From this point of view, therefore, it is no longer necessary to employ living bacteria in protective inoculations. Further, we now know that attenuation of virulence of bacteria is accompanied by very definite changes in the make-up of these micro-organisms, the change usually being the loss of something which is of importance antigenically. Therefore, according to our present knowledge, the use of living attenuated cultures for the production of immunity is possibly not the best method. With increasing knowledge of the nature of bacteria and their products as stimulators of anti-body formation, we can reasonably hope to produce more efficient and safer vaccines than have been used in the past. It seems possible also that we may be able to devise methods that will produce resistance in the animal body to bacterial diseases which, under natural conditions, do not appear to give rise to any very definite degree of resistance. It is possible that such methods might involve injections at intervals over a period of years if the resistance is to be prolonged, but the disadvantage would not be very great if the procedure were perfectly safe and easy.

Of recent years, studies of bacterial variation as well as studies of the chemical structure and the immunizing properties of bacterial antigens have explained in part, if not fully, many former difficulties and failures, and have placed the problem of bacterial immunity on a more secure basis.

Bacterial Variation.

The views on bacterial variation of earlier workers were largely based on the study of impure cultures. Of recent years, it has been clearly demonstrated that colony formation can be correlated with variation in other properties, many of which are of fundamental importance to the practical problems of immunity. Arkwright has shown that in plating cultures of laboratory strains of many bacteria two types of colonies may be found. One type is smooth and more translucent, whilst the other has a rough, matt surface, and is more opaque. He designated these varieties as "smooth" (S) and "rough" (R), respectively. The smooth colonies are associated with virulence, and the rough with loss of virulence. There are also other characteristics associated with these colonial appearances, such as that of spontaneous clumping in salt

solution and, sometimes, loss of motility by the rough cultures. Further, serological tests with monovalent sera show that the two types are antigenically specific, at least in the higher dilutions. These observations have been confirmed by many workers, and on many different species of bacteria.

It may be said that there is a general tendency for bacteria cultivated under artificial conditions to vary from smooth to rough, the variation being accompanied by loss of virulence and some antigenic constituents.

Associated with these studies are those of Weil and Felix, who showed that motile bacteria possessed two antigenic constituents responsible for the production of agglutinins in the inoculated or infected animals. These two constituents have been called H and O, respectively, the H being associated with the flagella of the bacterium, and the O with the body (somatic).

A further aspect of this subject was developed by Andrews, who showed that H agglutinins may be either "group" or "specific".

The conception has grown up of an antigenic "spectrum" within certain pathogenic species of bacteria, with groups or strains arranged in bands, as it were, which in some cases are sharply marked off, but in others shade into each other.

These observations are of fundamental importance, and help to illustrate the complicated nature of the bacterial organism, particularly with regard to its antigenic make-up.

Side by side with these studies are others which have been made by a chemical analysis of the bacterial cells, and the two taken together give us a new conception, and a new method of approach to the practical problems of immunity.

Chemical and Physico-chemical Studies.

It is only since more thorough knowledge of bacteria themselves, their physical and chemical structures, is being built up that we can see the possibility of much greater development in the application of this knowledge to the problems of immunity.

For many years, specificity in immunity reactions was considered to be wholly bound up with the structure of the protein. Landsteiner and his associates were responsible for demonstrating that the specificity of a large colloidal molecule may be determined by a comparatively small reactive group in that molecule, and he called this reactive group a haptene or partial antigen. This work has been carried on with protein substances, many of them very complex, to which have been linked more simple reactive substances, the most interesting, from our point of view, being some of the more simple carbohydrates. It has been shown that the specificity of these linked compounds is determined entirely by the chemical (and physical) properties of the carbohydrate or other substance linked with the protein. Two proteins with entirely distinct immunological characteristics can be made to give identical immunological reactions if linked in the same way with the same carbohydrate.

A considerable amount of work has been done on the chemical constitution of bacteria, but much of it has led to little knowledge of fundamental importance. Of recent years, however, results of the greatest importance have been obtained. Avery and Heidelberger, working with the pneumococcus, were able to show that a very important

product, apparently associated with the capsule and diffusible into the medium, was a carbohydrate substance, a polysaccharide very similar to the vegetable gums. Later, they showed that this substance determined the specificity of the organism, and that it differed chemically and immunologically in the three main types of pneumococci.

Since then, a mass of work is accumulating on similar lines, and many species of bacteria have been examined, and in each case it has been determined that the specificity of the organism resides very largely in the polysaccharide which is loosely bound to the protein of the organism.

This chemical work links up with the more purely bacteriological work of Arkwright and others. It has been shown that the variation from smooth to rough is associated with a loss of the specific polysaccharide, and that the O agglutinogen is likewise closely associated with the same substance.

The serum reactions which we have associated in the past with anti-bacterial immunity are shown now to be not necessarily proportional to the degree of resistance of the animal. Agglutinins may be produced quite easily by the inoculation of bacteria which have undergone rough variation, or have lost their virulence, and yet the animals possess no specific resistance to infection. Bacteria are shown to be very complex organisms, and it is necessary to know how they can be handled without loss of, or damage to, the specific substances before we can use killed suspensions for the stimulation of resistance to invasion by virulent members of the same species.

It is known that physical disruption of the bacterial cell may completely destroy the specificity of the antigenic substances present. Much of the handling that bacterial suspensions have been subjected to in the past can be calculated to destroy this specificity completely, whereas heat, which was for so long considered to be destructive of specificity, is now known not to be so, at least in the majority of cases.

General.

In this brief outline, an attempt has been made to indicate how this newer knowledge has opened up very promising fields for investigation. A vast amount of work still remains to be done and, although the way has been indicated, each species of bacteria offers its own special problem.

It is extremely difficult for the animal body to deal with some of the more resistant types of bacteria. The reactions of the animal body to the presence of a foreign protein or antigenic complex is probably fundamentally the same in all cases. Bacteria are, however, different from other foreign proteins in being particulate. Their antigenic specificity is destroyed by proteolytic enzymes, by physical disruption, and other changes. Being particulate, and not in soluble form, they do not constitute ideal antigens.

Future work will have to be directed towards an attempt to prepare bacterial antigens in a more suitable form while preserving their specificity. In this work the chemist will play a very important part, and each step will have to be controlled by crucial tests for specificity as understood in the light of the fundamental work briefly indicated above.

The Use of Creosote and other Tar Oils as Motor Fuels.

By L. J. Rogers, M.Sc., B.E.

Mr. Rogers was one of the first Australian graduates to receive a research studentship from the Science and Industry Endowment Fund. He left Australia in 1926, and after spending his studentship at the British Fuel Research Board's Station at Greenwich, he served for a period as a member of the staff of the Station. Recently, he returned to Australia in order to assist generally in liquid fuel problems. A short time ago he was asked by the Vice-President of the Executive Council (Senator the Hon. A. J. McLachlan) to furnish a report on the Australian possibilities of the use of creosote and other tar oils in motor engines. The article that follows is based on that report.—Ed.

1. Introduction.

The present world-wide depression in the market for tar products has inspired a number of investigations into alternative methods of utilization. Some prominence has been given recently to researches carried out in Ireland and England on the use of creosote as a fuel for internal combustion engines. To a country like Australia, situated very unfavorably as regards supplies of petrol, and possessing what may be considered unlimited reserves of high class coal, the possibilities revealed in these investigations appear very attractive at first sight. Creosote, however, is produced in such small quantities that it can never be more than a by-product of other industries, and the supply will always be limited by the demand for gas and coke. Nevertheless, at present, it is difficult to find a market for Australia's production, and a new use for it, as well as for other tar oils, would be welcomed by local distillers. In the following report, a brief survey is made of technical considerations in the application of creosote as a fuel for motor vehicles, and the economic aspect of the problem as it affects Australia generally.

2. Theoretical Considerations.

The nature of the fuel used in motor car engines is prescribed mainly by the conditions under which the vehicle is to operate. In the case of a private car, convenience demands that the engine shall be able to start directly upon the fuel in all weathers. The driver cannot be expected to waste his time and soil his hands in priming the cylinders or heating the induction pipe, so that the only permissible expedients for assisting ignition are the flooding of the carburettor and the use of a choke. On the other hand, a commercial vehicle may use a cheaper and less volatile spirit by resorting to priming, if necessary, when starting from cold. The petrol used by the London General Omnibus Company, for instance, consists of No. 2 spirit to which is added 30 per cent. of duty-free (heavy) fuel.

For satisfactory operation upon heavy fuels, it is necessary to heat the induction system by contact with the exhaust manifold. The minimum temperature of preheat is prescribed by the necessity for evaporating sufficient fuel to form an explosive mixture in the combustion chamber. The optimum temperature, however, is determined by

the tendency of the fuel to condense in the induction pipe. If condensation is allowed to occur, the response to the throttle will be sluggish, and the distribution of the fuel between the different cylinders of the engine will be uneven. Loss of power and efficiency will ensue, and the performance of the engine will be impaired generally. A certain amount of preheating of the fuel and air is arranged for in the average car, to enable a cheaper fuel to be used than would otherwise be possible. But the temperature to which the air must be heated for consuming kerosene is much higher than for normal petrol. The heating of the charge in this way reduces the weight of fuel and air which is drawn into the cylinder at each suction stroke. The use of heavy fuels therefore entails a loss of power in the engine which may be quite considerable. For this reason, racing engines and aeroplane engines do not have heated induction systems, and are obliged to use volatile spirits for satisfactory performance.

In the case of petroleum oils, it is found that the tendency to detonate increases with the density of the fuel. Engines designed to use heavy fuels—tractors, for instance—therefore have low compression ratios. This involves a further loss of power, and a pronounced reduction in efficiency. In one particular case, it has been found that the power output of a certain petrol engine was reduced altogether by 17 per cent. when adapted to burn kerosene.

Low volatile fuels condense readily on the walls of the engine cylinder. The low temperature of the liquid film on the cylinder walls and its comparatively poor access to oxygen result in incomplete combustion and the formation of carbon. Unburnt fuel is scraped by the piston rings into the sump, where it contaminates the lubricating oil. The use of heavy fuels therefore necessitates more frequent draining of the sump and renewal of the oil. To minimize these disabilities, it is desirable to maintain the temperature of the cooling water, and thereby that of the cylinders, as high as is possible without risk of local overheating. The formation of carbon on hot spots, such as valves and piston heads, is favoured by the fact that heavy petroleum hydrocarbons are more easily decomposed by heat than are lighter fractions. The use of kerosene therefore involves more frequent overhauls, with increased costs for maintenance and loss of services while the vehicle is under repair.

The advantages and disadvantages of using a heavy fuel in a motor vehicle may be summed up as follows:—

For—

Reduced cost of fuel per gallon.

Higher mileage per gallon in virtue of its greater calorific value per unit volume, and in spite of its lower efficiency.

Lower inflammability.

Of these three items only the first is of great importance.

Against—

Lower power output from a given engine, or, alternatively, the extra cost of a larger engine for developing the same power.

Higher maintenance costs.

More frequent renewals of lubricating oil.

The utilization of tar oils instead of heavy petroleum is favoured by the high anti-detonating value of aromatic hydrocarbons as compared with paraffins and naphthenes. Creosote can be used in a car

engine with no reduction in compression ratio and consequent loss of efficiency. Indeed, it is possible to use a higher compression than is normal in a petrol engine. Owing to the stability of aromatic hydrocarbons, moreover, it might be expected that the deposition of carbon in the cylinder head would be reduced. This expectation may not be fulfilled in practice, however, for benzol, presumably on account of its slow burning characteristics, is found to make at least as much carbon as aliphatic petrols. Creosote suffers from the disadvantages of a lower calorific value, a propensity for forming gums by oxidation and polymerization, and possibly a tendency for depositing pitchy material in contact with paraffin base lubricatng oil.

3. Experience in Belfast and England.

The first attempts to employ creosote as a motor fuel on a large scale were made in Belfast in March, 1929. Technical difficulties have been so far overcome that a number of buses operated by the Belfast Omnibus Company have been using the fuel for nearly two years. The application of creosote is now reported to be spreading to private cars.

The alterations and additions to the equipment of the Belfast buses, for adapting the engine to the new fuel are as follows:—

1. A new induction system surrounded by, and cast integrally with, the exhaust manifold. This intake has been patented by the Solex Company.
2. A second carburettor—of the horizontal Solex type—for use when running on creosote.
3. A separate tank and feed line for the creosote fuel.
4. A second accelerator pedal, with automatic arrangements for closing the petrol throttle when the creosote carburettor is in action, and for allowing a limited quantity of petrol to pass when the creosote throttle is closed.

The engine is started with petrol in the usual way, and kept running on this fuel until the exhaust manifold is hot enough to vaporize the creosote. The second accelerator is then used, automatically shutting off the supply of petrol. When running idle, the creosote throttle is closed, and petrol automatically substituted for the heavier fuel. After temporary stoppages for picking up and setting down passengers, the bus is driven off directly on creosote.

The fuel used at Belfast is prepared from high temperature tar produced in Glover-West vertical retorts. The crude tar is distilled, and the fraction boiling between about 180 deg. C. and 300 deg. C. is washed and mixed with 10 per cent. of water-white solvent naphtha to keep naphthalene in solution. The motor fuel prepared in this way has a specific gravity of 0.951, a tar acid content of 15 per cent., and a closed flash point of 129 deg. F. It is understood that the fuel may be purchased for 6d. per gallon.

The Belfast authorities have not fitted their buses with a high compression head in preference to the normal cylinder head. Their saving in fuel, therefore, cannot exceed that indicated by the respective calorific values of creosote and petrol on a volumetric basis, viz., about 8 per cent. With the carburettor correctly adjusted in each case, there is no reason why creosote should be more efficient than petrol. Indeed the

difference, if any, should be in favour of the more volatile fuel. The "pull" of the engine has been described as very satisfactory. This is probably due to the fact that the engine can be run at low speeds and full throttle without detonating. Changing down on hills may therefore be avoided in some cases, but there can be no doubt that a dynamometer test would indicate a deficiency in power.

One of the greatest objections to the use of heavy fuels in internal combustion engines for vehicles is the smoke and smell discharged from the exhaust. When the engine is rather cold, as, for example, after a short stoppage, combustion is imperfect, and fumes appear in the exhaust gases. This has proved an objection to the use of Diesel engines in buses, and the same trouble apparently is experienced with creosote. The smell of creosote is not as objectionable as that of burnt oil, being on the contrary rather wholesome. It is probable that this trouble will be overcome and that satisfactory operation will be made possible in city streets.

Investigations have also been carried out by the Manchester Corporation, the Gas Light and Coke Company, and the London General Omnibus Co. The most interesting fact arising out of the Gas Light and Coke Company's experiments is the possibility of using a heavy creosote prepared by distilling to pitch. The fuel used consists of creosote boiling between 180 deg. C. and 350 deg. C., with the addition of 20 per cent. of benzol. Horizontal retort tar is employed in this instance, so that the proportion of solvent required is increased.

The original Belfast arrangements were modified by the Gas Light and Coke Company by constructing a manifold of its own design, and by using a single carburettor with a change-over switch in the fuel line. To take advantage of the opportunity for increased fuel economy, and to compensate to some extent for the loss of power due to lower volumetric efficiency, the compression ratio of the engine has been increased from 5 : 1 to 6.6 : 1.

For satisfactory performance on heavy creosote, the temperature of the cooling water needs to be maintained above 80 deg. C., and the temperature of the induction pipe above 230 deg. C. When this temperature falls below the figure mentioned, fumes appear in the exhaust, and the response to the throttle is sluggish. With the engine idling, the temperature falls to 230 deg. C. in half an hour, and the throttle must then be opened slowly until the induction system is hot once again. If the temperature falls below 230 deg. C., petrol must be used for warming up. The time required for heating up from cold is about five minutes.

The secret of satisfactory preheating of the fuel and air appears to consist in having a heavy manifold with a substantial heat capacity. The induction pipe should be designed to prevent direct impingement of the fuel on the exhaust manifold, or local overheating will lead to the formation of pitch.

4. Sources of Supply.

Creosote suitable for use as a motor fuel may be prepared from coke-oven tar, horizontal-retort tar, or vertical-retort tar. The main product of each of these tars is a material for road dressing, which contains about 72 per cent. of pitch and 28 per cent. of oils. The presence of the lighter oil is required to

keep the product sufficiently fluid. In England the pitch contents of the three tars mentioned are respectively 70 per cent., 65 per cent., and 55 per cent. The mere removal of water and benzol from coke-oven tar produces a satisfactory road material, so that no creosote is available for other purposes. In concentrating the pitch content of horizontal retort tar from 65 per cent. to 72 per cent., very little creosote is prepared as a by-product. In the distillation of vertical retort tar, however, the residue of creosote would amount to approximately 20 per cent., or 2.7 gallons per ton of coal carbonized under English conditions.

The demand for road tar in England is rather slack at present, but in normal times the market would probably absorb all the road tar available. On the assumption that crude tar is distilled for road binders alone, the annual production of creosote in England would be approximately as follows:—

——	Coke Ovens.	Horizontal Retorts.	Vertical Retorts.
Coal carbonised, tons ..	17,000,000	8,000,000	10,000,000
Creosote available, gallons ..	..	5,000,000	27,000,000

The production of pitch for briquetting purposes by further distillation of tar would make available about 25 extra gallons of creosote oil for every 100 gallons of tar so treated. The normal production of pitch in the United Kingdom is about 500,000 tons annually. At present the quantity is reduced, but in more settled times the extra amount of tar oils prepared by distillation to pitch may be taken as approximately 38,000,000 gallons. The total supply is therefore about 70,000,000 gallons annually. Of this quantity, the greater part is required for wood preservatives, disinfectants, exports, &c., but a certain amount is at present being burnt as a fuel oil, either as creosote itself or as a constituent of crude tar. The quantity of tar oils which could be prepared for use in motor vehicles without encroaching upon other markets would therefore be only a fraction of 70,000,000 gallons. In view of the fact that England imports 1,000,000,000 gallons of petrol annually, and that the London General Omnibus Company alone uses 35,000,000 gallons, the supply of creosote is seen to be almost insignificant.

In Australia, the pitch contents of coke-oven, horizontal-retort, and vertical-retort tars are respectively 65 per cent., 58 per cent., and 48 per cent. A good road material may be prepared from local coke-oven tar merely by distilling off the water and benzol contained in it. Only 50,000 tons of coal tar per annum are carbonized in horizontal retorts, and then only in small works which do not distil their tar. The consumption of coal in vertical retorts is 1,000,000 tons per annum, yielding, on the average, 22 gallons of tar per ton. The creosote potentially available by distillation for road tar alone is therefore approximately 6,000,000 gallons per annum. In Australia, there is no market for pitch for briquettes, so that the supply of tar oils could not be increased by further distillation for this purpose.

It is not possible, by distillation alone, to prepare a first-class road binder from tar made in vertical retorts from Australian coal. Difficulty is experienced, therefore, in selling road tar in competition with bitumen. Consequently, large quantities of crude tar, amounting to about half the production, are being burned under boilers and stills for want of a more profitable market. If a demand were to arise for creosote motor fuel, this tar could be distilled to a soft pitch for the production of creosote, leaving a residue which might still be used as a boiler fuel, or which alternatively could be returned to the retorts for gas making. It is difficult to estimate the amount of oil which might be prepared from crude tar which at present is being used as a fuel oil, but the quantity would be of the order of 4,000,000 gallons per annum. Further supplies could be secured only by offering prices in excess of the present market rates, and in normal times the quantity available would be considerably less. The value of creosote at Australian gas works is approximately 6d. per gallon, so that a mixture containing 10 per cent. of benzol could probably be delivered in bulk to large consumers for about 9d. per gallon. It may be found, however, that the addition of a solvent to Australian creosote is unnecessary.

The amount of creosote potentially available for consumption as a motor fuel is small compared with Australia's total requirements of about 200,000,000 gallons of such fuel per annum. The utilization of creosote, therefore, is not a question of national importance. To gas works, however, and to transport companies also, the possibility of operating motor vehicles on tar oil fuels should be of considerable interest.

5. Markets for Motor Fuel prepared from Tar.

Owing to the limited and localized supply, the use of creosote must be restricted to the various metropolitan areas. The market for the fuel, moreover, will be restricted to concerns operating fleets of vehicles under expert supervision and with frequent inspections for repairs and renewals. In Australia, bus companies do not appear to be organized on the large scale which is common in England and America. It should be possible, however, to find a market for creosote with transport companies, business firms, and railway departments, if the fuel can be offered at an attractive price. Creosote as a motor fuel can only displace second grade spirit, sold at 1s. 9d. or 1s. 10d. per gallon, resulting in a possible saving of 60 per cent. in fuel costs. Under different conditions, the cost of petrol amounts to between 15 per cent. and 40 per cent. of the total running expenses of a vehicle. For the present purpose, a round figure of 25 per cent. may be adopted, so that the saving to be effected by adapting a vehicle to tar oil fuel will be 15 per cent. of the total expenses. Against this economy, there must be debited the extra cost of maintenance. It cannot be doubted that the net saving to be effected by the substitution of tar oil for petrol is very material, but a company with only a few vehicles in its employ probably would not be encouraged to spend money on adjustments and alterations for an economy of the order of 10 per cent.

In some respects, creosote would appear to be an ideal fuel for tractors. These engines are designed for consuming kerosene, and would operate satisfactorily on a light grade of creosote without further modification. The value of tar as a tractor fuel, however, is discounted

by the necessity for using it as quickly as possible after distillation. If creosote is allowed to stand for a few weeks it forms gums, which would cause endless trouble in the induction system of a motor engine. For this reason alone, it would not be wise to attempt the sale of tar oil as a power kerosene.

If creosote is ever adopted on a large scale as a motor fuel, it is to be expected that bus and lorry engines will be built for the consumption of other heavy fuels, such as kerosene. The mere fact that such developments have not yet taken place suggests that manufacturers do not consider, at present, that heavy oils can compete with motor spirit. Although power kerosene is retailed at 1s. 2d. per gallon in the capital cities, it can be landed into Australia for 7d. or 8d. per gallon. On a heat-value basis, this price is equivalent to the probable cost of production of a creosote-benzol mixture at the gas works. If a large demand were to arise for heavy motor fuels, therefore, oil companies would be in a position to sell kerosene at competitive prices.

It must not be overlooked that another competitor in the utility vehicle field is making fairly rapid progress in England and the Continent of Europe. Diesel engines are becoming popular for heavy duty, and more interest is being taken in these vehicles by bus companies and similar concerns than is being shown in creosote. Diesel engines possess all the advantages, and do not suffer from the limitations, of the creosote engine. It may be that in the near future the value of creosote as a motor fuel must be compared with Diesel oil instead of No. 2 motor spirit or kerosene. In such a competition, the advantage would undoubtedly rest with the petroleum fuel, for creosote itself cannot be used in a Diesel engine, and can only be adapted to the less efficient vaporizing oil engine.

6. Conclusions.

It has been demonstrated at Belfast and elsewhere that a motor engine can be adapted to consume tar oils instead of petrol. The performance of a vehicle on a heavy fuel is quite satisfactory, and the comparatively low price of creosote should appeal to transport companies and similar concerns operating large fleets of vehicles. The supply of creosote in Australia is limited to the larger cities, and only 4,000,000 gallons, approximately, could be made available at the present market price of tar oils. If a demand should arise for large quantities of heavy motor fuel, it is likely that kerosene also will be sold for the purpose. Creosote would then have no advantage in cost of production over other fuels. It is likely, therefore, that the consumption of tar oil as a motor fuel will be limited to the quantity which is at present being used for firing boilers and stills. This amount represents only a very small contribution to Australia's total requirements of motor spirit. It is very desirable that the utmost use should be made of home-produced fuels, but it would be very unwise to anticipate any considerable developments in the employment of creosote as a motor spirit.

To companies owning only a few vehicles, the possible saving in fuel would not justify the expense of the necessary alterations to the engine. The economies to be effected by large concerns, favorably situated for purchasing and using creosote, are fairly considerable, however, and co-operation with the gas companies on this subject should be to their mutual advantage.

Tasmanian Soils in Relation to Tree Growth in Plantations of *Pinus radiata* (*insignis*) and other Exotics.

*By C. G. Stephens, M.Sc.**

The following article has been prepared from a rather full report written by Mr. Stephens, of the Division of Soils, primarily for the Tasmanian Forestry Department. In addition to giving detailed descriptions of the various types of soils on which pines have been planted in Tasmania, the report puts forward evidence in support of the contention that the acidity of the soils has a very important bearing on the well-being of the trees. As such a finding may have a much more general application than to Tasmanian soils, and in view of the somewhat widespread interest that is now being taken in Australia in the planting of pines and other exotics, it has been decided to publish the material that follows.—Ed.

Summary.

1. An examination of the soils of several forest plantation areas in Tasmania has been made.

2. Over the pH range (3.5–5.5) of the soils examined, the pH value was found to be much more significant than plant food values in controlling the vigour of the trees, low pH values in most cases being accompanied by the death of the trees.

3. Those soils of low pH value (3.5–4.5) were almost invariably very sandy, strongly podsolised soils, clay and silt being present in almost negligible quantities. These soils were also characterized by a heath vegetation, a feature of which was the predominance of *Sprengelia incarnata.*

4. Those soils of higher pH value (4.5–5.5) were characterized by a heavier texture than a sand, varying from a sandy loam to a denuded light clay. The vegetation on these soils was very different from that on the lower pH range, being of a rain or sclerophyll forest nature.

5. A correlation co-efficient of .8 was found between the vigour of *Pinus radiata* and the pH value of the soil.

1. General.

When the classification of the major soil types in Tasmania was commenced by the Division of Soils in 1931, the Departments of Agriculture and of Forestry undertook to co-operate in the work. The Forestry Department has an interest in the relationship between soil type and forest growth, and is particularly concerned as to the possibility of planting the poorer types of soils with exotic conifers and other trees. As a result of difficulties experienced with these poor soils in various parts of the State, the Department came to the conclusion that a careful investigation was desirable, with the result that the study which is the subject of the present report was undertaken.

Generally speaking, the areas utilized for softwood planting in Tasmania amount to several hundred acres, and have been what is termed third class land, often of the poorest quality, first and second class land usually being regarded as of greater agricultural than sylvicultural value. No extensive attempts have been made to plant the button-grass plains, which occur in large areas in the western half

* An officer of the Division of Soils and located at the University of Tasmania, Hobart.

of the State, although a definite interest in that direction has been taken in them. On the poorer types of third class land, the trees have failed extensively. This is the case particularly at Strahan and Sisters' Hills, but where the plantings are on a different soil type—although included in the general broad classification of third class—namely, at Queenstown, Beaconsfield, and a small portion of Sisters' Hills, quite good results have been obtained.

At Strahan the plantation is situated entirely on ancient sand dunes which have been extensively re-worked, and which, except near the shore, and where they have been broken up to form sand-blows, retain practically no resemblance to the beach sand from which they are derived. The slopes of these dunes vary from gentle to moderate.

Sisters' Hills is situated on an extensive area of pre-Cambrian sandstone, the topography of the country being very steep, except for some areas of gentler slopes in some of the broader valleys.

Both the Beaconsfield and Queenstown areas are situated in country the rocks of which have a very complex petrographic nature. At Beaconsfield there are present gabbro, serpentine, slates, and schists, as well as areas of more recent rocks. At Queenstown the predominant rocks are felsites, gabbro, and serpentine. The slopes on the average, in both cases, are moderate, though flats and steep slopes both occur.

Thinking that the failure of the trees on certain areas might be due to the absence of mycorrhiza-forming fungi, the Forestry Department inoculated some of the areas at Sisters' Hills with soil from more successful areas. This produced no result.

Although the literature on the subject is somewhat indefinite, it is generally considered that the formation of mycorrhiza is essential for the successful growth of pines. With this idea in mind, one dozen two-year-old *Pinus contorta* plants of various heights and shades of green and yellow were handed to Mr. W. M. Carne, of the Division of Plant Industry, for examination. He reported that abundance of root growth, abundance of mycorrhiza, and mycorrhizal activity in general decreased as the trees became more yellow and, with one notable exception, as the size of the trees decreased. The exceptional tree, however, fitted in the colour gradient. Mycorrhiza was present in all cases.

Hence it is practically certain that the failure of the trees in this case is not due to the absence of mycorrhiza-forming fungi. However, it is possible that the soil conditions themselves, by controlling the abundance of the fungi, indirectly control the vigour of the trees.

2. Soil Types and Analytical Data.

The full report contains detailed descriptions of the various types into which the soils have been classified, and also the results of mechanical and chemical analyses. Accounts of the native vegetation occurring on the various types are also given.

Because of the indications presented by the state of the trees and the type of natural vegetation present, it was decided to regard the determinations of soil acidity (pH) as the major part of the investigation, and as being likely to yield the most important results. Accordingly, nearly three hundred pH determinations in all were made, the quinhydrone electrode being used throughout. The results are classified

in Table 1. In addition, certain indications were noticed that pointed to a probable deficiency of potash, phosphates, and nitrogen in most of the soils. Hence both available potash and phosphate and total nitrogen were determined on samples from each of the soil types.

All values for available phosphate for surface soils except one were either low (0.0025 per cent.) or very low (0.00012 per cent.), but one value (0.0066 per cent.) approached a moderate figure. Similarly, all values for available potash for surface soils were either low (0.0050 per cent.), or very low (0.0012 per cent.). Some of the latter values may be regarded as extremely low.

The figures for total nitrogen varied from low (0.0364 per cent.), to high (0.3388 per cent.) values.

3. Conditions of the Trees and their Correlation with Analytical Data.

At Strahan, on soil type S1, the trees planted seem to be doing very poorly. Over the whole area, the trees are of a decidedly yellow colour, and on the average have attained a height of approximately only 18 inches for several years' growth. Quite a percentage are dead, but occasional trees, in hollows, seem to have done fairly well. On two areas that were ploughed before planting, a little improvement in the height was noticed. In addition, some work has been carried out on a few experimental plots. Several fertilizers have been used and, in the case of bone and superphosphate together, superphosphate alone, blood and nitrate together, blood and superphosphate together, and blood and bone together, all trees show some increase in height, being in a few cases up to 30 inches high, but they are still yellow and well below normal growth. On one plot where lime had been used, no effect was noticeable. On soil type S2 the trees show a slight improvement on the above, being of a greater average height in general, and of a better colour, although not a normal green.

At Sisters' Hills, on both soil types SH1 and SH2, the trees have failed consistently, those on type SH2 being much the worse. All trees are yellow, those on type SH2 being particularly bright in colour, and in both cases they are of a very low height, those on SH2 again being the worst. No very definite general figure for height is possible, owing to the different species and ages of the trees planted, and the fact that many plots were frequently refilled. On the whole, the oldest of those that have survived have made very poor growth. A large proportion of the trees on SH1, and a very large proportion on SH2, have died. Some of the trees have been planted on mounds about 6 inches high—a practice that seems to have effected a slight improvement. Where some stump has been burnt in the ground and the tree planted in the remains a noticeable improvement in height suggests that potash is somewhat deficient in these soils—an assumption verified by the analytical data. The growth of the trees on type SH3 is particularly good, both in height and colour.

At Beaconsfield, on type B1A, the growth of the trees on the whole may be classed as good, e.g., trees eight years old are in many cases over 20 feet high. There is some variation in height, but the colour is generally normal. The same remarks apply to B1B. except that there is rather more variation in height. On type B2 there is considerable variation, from quite poor results in both colour and height, to quite

normal growth. Type B3 exhibits the worst results at Beaconsfield, there being generally a variation from very poor to very fair results, colour and growth being in some cases as bad as at Sisters' Hills on type SH1.

On both types, Q1 and Q2, at Queenstown, the trees seem to be making very fair growth, and are almost normal in colour. In this case, only *Pinus pinaster* is considered, as the other two species planted appear to be suffering to some extent from the small percentage of sulphur dioxide* still in the atmosphere, although they continue to make fair growth. *P. pinaster* does not appear to be affected.

Some leaf fusing and *Chermes* were noted on the various areas, particularly at Beaconsfield.

The data and analytical results are classified in Table 1.

4. Conclusions.

The major results of the investigation seem to indicate that it is useless to attempt to plant exotic and other species of softwoods on natural soils with a pH value of less than 4.0, and that on soils with pH values between 4.0 and 4.5, failure is comparatively certain or, at best, on the better textured soils only fair results will be obtained. In the latter pH range, an efficient drainage scheme and/or a different method of planting, e.g., an elaboration of the mound planting tried at Sisters' Hills, may improve results, especially on the better soils. Generally speaking, the soils with pH above 4.5 should give good results, and those above pH 5.0 excellent returns. The value pH 4.0 may be regarded as the limiting value for the survival of exotics in general, although it was continually noticed that some species withstood greater acidity (lower pH) better than others. This was particularly noticed in the case of *Pinus contorta,* which seems to do comparatively well down to pH 4.0; e.g., on an area from which the samples were all between pH 4.0 and 4.5, and where *Pinus radiata, Picea stichensis, P. excelsa, Larix europea, Sequoia sempervirens,* and *Tsuga albertiana* had all failed, *P. contorta* is showing up splendidly, and putting forth good shoots. It is possible to observe numerous examples of the above phenomena, but there is need for further elaboration of the work to place the species in some definite order of tolerance to acidity.

Another prominent fact is the marked relationship between the physical characteristics of the soils, and the growth of the trees. In all cases where the soils are completely podsolised sandy soils, the trees have grown very poorly. Since such completely podsolised sands are, under the climatic conditions prevailing in Tasmania, naturally very acid in reaction, then the connexion between the growth of the trees and the texture of the soil can be readily followed. Where the trees have been successful they are almost invariably on soils heavier than sands.

Despite the observations in the field having shown that the trees will respond to increments of phosphatic, potassic, and nitrogenous fertilizers, an examination of the estimations of the plant foods and total nitrogen on the samples from the various soil types indicates that the vigour of the trees is probably not very largely determined by the amount in which they are present, but rather that the pH value is more significant. For example, type B3 is high in nitrogen, while B1a is low; but the trees on

* From the Mt. Lyell smelters.

TABLE 1.

Soil.		Trees.			Reaction.		Plant Nutrients.		
Type.	Texture.	(a) Height.	(b) Colour.	(a) and (b) Variation.	Mean pH.	Standard Deviation.	Available P_2O_5.	Available K_2O.	Total Nitrogen.
S1 ..	Poor—sandy ..	Poor ..	Yellow ..	Very little	$< 4\cdot5$ ..	Small ..	Very low ..	Very low ..	Low
S2 ..	Poor—sandy ..	Poor—fair	Slight yellow	.. ..	$< 4\cdot5$ ..	.. ..	Low ..	Very low ..	Low
SH1 ..	Poor—sandy ..	Poor ..	Yellow ..	Very little	$< 4\cdot5$ ..	Small ..	Very low ..	Very low ..	Low
SH2 ..	Poor—sandy ..	Very poor	Very yellow	Very little	Much $< 4\cdot5$	Small ..	Very low ..	Very low ..	Moderate
SH3 ..	Good—loamy ..	Very good	Green ..	.. ..	Much $> 4\cdot5$	.. ..	Moderate	Low ..	High
B1A ..	Good—sandy-loam ..	Good ..	Green ..	Some ..	$> 4\cdot5$ ..	Moderate ..	Low ..	Low ..	Low
B1B ..	Very fair—clay-loam	Good ..	Green ..	Some ..	$> 4\cdot5$ ..	Moderate ..	.. ..	.. ..	Low
B2 ..	Fair—fine-sand ..	Very fair ..	Green ..	Big ..	$> 4\cdot5$ ..	Large ..	Low ..	Low ..	Low–moderate
B3 ..	Poor—sandy ..	Poor ..	Yellow ..	Big ..	$< 4\cdot5$ ..	Large ..	Low ..	Low ..	High
Q1 and Q2 ..	Very fair—silty ..	Very fair ..	Green ..	.. ..	$= 4\cdot5$ ..	.. ..	Low ..	Very low ..	Low–moderate

B1A are much better than those on B3. Since both phosphate and potash are low in both types, this difference is most probably due to the difference in pH values, that of B1A being higher than that of B3. Owing to the general poorness of all soils except SH3 in phosphate and potash, these figures are not so readily interpreted, but the fact that trees show quite good growth on such soils as B1A, which are as poor in phosphate and potash as some of the soils where the trees are doing very poorly, indicates that the paucity of these plant foods is by no means the limiting factor in the growth of the trees.

This conclusion as to the importance of an optimum pH range, rather than an abundance of plant foods, was verified by the strength of the correlation of the vigour of *Pinus radiata* for which sufficient data was available with the pH values of the soil samples taken from the hole in the immediate vicinity of which the height of the young trees was estimated.

To overcome the difficulties associated with curved regression lines and partial correlation co-efficients caused in this case by the different ages (0–9 years) of the trees measured, and the fact that the age at death, as distinct from age at date of observation, was not known, the heights of the trees at different ages were compared as ratios with the heights at corresponding ages of an arbitrary standard *Pinus radiata,* thus reducing the problem to one involving direct correlation and straight line regression. The ratio of the heights was defined as the vigour of the trees. The heights of the standard tree at various ages are shown in the following table:—

Age (years)	0	1	2	3	4	5	6	7	8	9
Height (feet)	1	2	4	6	9	12	15	19	23	27

Whatever the age at death, or date of observation, if the great majority of the trees near the hole were dead, and the remainder at a standstill, the vigour was taken as $<.2$, and placed accordingly in the correlation table, together with the other values of which there were eighty in all. The following is the correlation table:—

Reaction (pH).

Vigour.	3·4–3·6	3·6–3·8	3·8–4·0	4·0–4·2	4·2–4·4	4·4–4·6	4·6–4·8	4·8–5·0	5·0–5·2	5·2–5·4	5·4–5·6	Total.
1·6–1·4										½	½	1
1·4–1·2								1		1		2
1·2–1·0				½	1		2¾	1¼	2	½		8
1·0–·8				1½	2	½	2¾	2¼	1			10
·8–·6				2	3	2	1	5	½			13½
·6–·4		1		3	3½	5						12½
·4–·2			2		1	3						6
·2–0·0	2½	6	3½	6	7½	1½						27
Total	2½	7	5½	13	18	12	6½	9½	3½	2	½	80

It is obvious from the above table that there is a marked positive correlation between pH value of the soil and the vigour of the trees. The angles formed with the axes by the two regression lines calculated and plotted from the above table give a positive correlation co-efficient of .8. From Fisher's tables, the co-efficient for the .05 level of significance and 78 degrees of freedom (80 double entries) is .214, so that the result of .8 is undoubtedly significant.

The arbitrary standard *Pinus radiata* was suggested by the Conservator of Forests, Hobart, and its growth curve forms an almost exact fit to the equation $(h - 1) = k.a.^{3/2}$, where $k = 0.96$, $h =$ height in feet, and $a =$ age in years. Other arbitrary standard trees, if used, would, by virtue of their different total heights, merely cause a change of scale of the regression lines. If the yearly growths did not fit the above equation, then there would be a re-arrangement of the points about the regression lines, but they would actually change the position of the lines which are fitted by the law of least squares, little, if any.

Hence it appears that over the pH range (3.5–5.5) of the soils examined, in the case of *Pinus radiata* at least, and there is every indication that it is true of many other species, the pH value of the soil is of major importance in determining the vigour of the trees.

5. Acknowledgments.

During the course of the work, the author was greatly helped in many ways by the Conservator of Forests, and several members of his staff. Also Professor J. A. Prescott, Chief of the Division of Soils, Council for Scientific and Industrial Research, helped considerably by his advice and criticism of the various phases of the work. Professor E. J. G. Pitman, of the University of Tasmania, looked over the mathematical portion of the work. To them the author tenders his sincere thanks.

PLATE 1.

(The Animal Health Research Station, Townsville. See page 61.)

FIG. 1.—General view of laboratory building from south-east.

Fig. 2.—Isolation paddocks for experimental cattle. Erected in the coconut palm grove with each pen carefully buffered. A group of cattle used in contagious bovine pleuro-pneumonia is seen. November, 1932.

FIG. 3.—General laboratory (bacteriological and biochemical). Unfortunately the photographer included the then incompleted stairway. November, 1932.

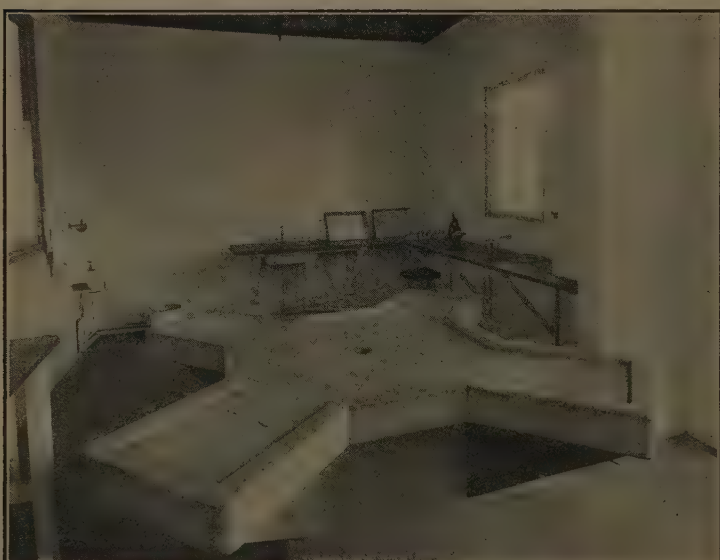

FIG. 4.—Post-mortem room in concrete annexe. November, 1932. The unique design was reproduced from Continental literature.

NOTES.

The Animal Health Research Station, Townsville.

In recent issues of this *Journal* (e.g. Vol. 5, No. 2, p. 131, and Vol. 5, No. 3, p. 193), references have been made to the cattle investigations in which the Empire Marketing Board, the Queensland Government, Queensland cattle producers, and the Council are co-operating. The main laboratory in which this work is centred is at Oonoonba, some 6 miles outside Townsville, and was made available for the work by the Queensland Government. Subsequently, however, various modifications were made to the various buildings in order to make them more suitable to the particular programme of investigations mutually agreed upon by the co-operating parties. Some recent photographs of the Station have now been obtained, and four selections from them are reproduced in Plates 1 and 2 (facing page 60).

The Thomas G. Sloane Collection of Insects (Coleoptera).

The late Mr. Thomas G. Sloane, a well known sheep breeder of "Morilla" Station, near Young, N.S.W., was a keen collector of beetles, and became one of the leading specialists in the world on the great group of Caraboidea or Ground Beetles and their allies. It had been his intention to retire to Canberra and spend the last years of his life working at his favorite hobby, and he had expressed his intention of leaving his collection to the Museum of the Division of Economic Entomology, C.S.I.R. His death occurred before he could give effect to his wishes, but Mrs. Sloane has very generously donated the collection to the Council.

The collection consists of many thousand specimens of Caraboid beetles and is divisible into two main sections—(*a*) Mr. Sloane's collection proper, containing only Australian species, and housed in a large cabinet; (*b*) the famous van der Poll collection, containing Caraboidea of the whole world, in about 300 continental cartons, purchased by Mr. Sloane during his last visit to Europe. In the Australian portion of the collection there are a large number of valuable type specimens.

Besides the collection, the Council has secured a complete autographed and annotated set of Mr. Sloane's publications, fifty-five in number, which will be of very great value to any specialist wishing to make use of the collection.

Entomological Investigations—Gift of £500 by Sir MacPherson Robertson.

The Council has recently received a very generous gift of £500 from Sir MacPherson Robertson, the well-known confectionery manufacturer of Melbourne. The gift consists of £200 for capital expenditure and £100 per annum for three years. It is known that Sir MacPherson would welcome researches into insect pests of stored food products, but nevertheless he has made his gift quite unconditionally.

It is proposed to utilize the capital grant for the erection at Canberra of temperature and humidity control apparatus in which entomological studies of the nature Sir MacPherson has in mind may be undertaken. Plans for such apparatus are now being prepared.

The Blowfly Problem.—Forthcoming Comprehensive Report.

Elsewhere in this issue (page 70) a brief reference is made to the forthcoming publication of the Joint Blowfly Committee's report on the blowfly problem.

This Committee is a body that has been established by the Council and the New South Wales Department of Agriculture acting in conjunction. Its main purpose is to co-ordinate the blowfly researches of the two bodies, and to advise generally in regard to that work or to the initiation of investigations into other aspects of the main problem. It is constituted as follows:—

Dr. J. A. Gilruth, Chief, Division of Animal Health, C.S.I.R. (Chairman),

Dr. R. J. Tillyard, Chief, Division of Economic Entomology, C.S.I.R.,

Dr. H. R. Seddon, Director of Veterinary Research, N.S.W. Department of Agriculture, and

W. B. Gurney, Entomoligist, N.S.W. Department of Agriculture,

with Dr. I. M. Mackerras, of the Division of Economic Entomology, C.S.I.R., as Secretary.

At an early stage after the Committee's formation, it considered that the publication of a statement which would summarize the work already done on the problem and the present stage of knowledge of the problem was advisable. It was realized that such a statement, if published, would be of value, not only to the sheep-owner, but to research workers generally throughout Australia and other countries.

This suggestion was approved and a report has now been prepared. It will be ready for publication almost immediately. It is written in language as simple as possible, consistent with exactitude, and comprises 136 pages of subject-matter, together with a number of text figures of larvae, traps, &c., a number of photographs of interest, and a coloured frontispiece showing each individual species of blowfly associated with strike. It will be possible, by reference to this coloured frontispiece and to the accompanying descriptions, for any one to determine the nature and importance of any blowfly which he may capture. The various sections of the report are as follow:—(i) the blowflies concerned, (ii) description of strike, (iii) origin and spread of strike, (iv) earlier scientific investigations, (v) later scientific investigations, (vi) geographical and seasonal distribution of flies, (vii) blowfly biology: habits and life-histories, (viii) blowfly biology: relation to environment, (ix) factors influencing fly abundance, (x) susceptibility of individual sheep, (xi) general waves of fly-strike, (xii) general observations of measures for combating strike, (xiii) crutching, (xiv) jetting, swabbing, and dipping, (xv) dressings, (xvi) breeding to reduce susceptibility, (xvii) fold removal operation, (xviii) biological control, (xix) trapping, (xx) carcass treatment, (xxi) facilities for research, and (xxii) scope of the present investigations.

The report will be issued as a joint publication by the two co-operating parties, but at the same time will be incorporated by each organization in one of its regular series of publications, namely, the Council's series of Pamphlets and the Science Bulletin series of the New South Wales Department of Agriculture.

The printing of the report has been rather costly, and it will be necessary to make a small charge (1s. 6d. per copy).

The Occurrence of Anaplasmosis in Cattle in North Australia.

Hitherto, it has generally been accepted that the only blood parasite transmitted by the cattle tick (*Boophilus microplus*) in Australia is the piroplasm which produces the disease known as redwater or tick fever. For some considerable time, however, there has been very good reason for believing that other blood parasites existed, these being also transmissible from affected to healthy animals by the same tick and possibly by other vectors. One of these parasites is known as the anaplasm, discovered by Sir Arnold Theiler in 1910 in cattle in South Africa, and since determined to have a very wide distribution throughout the tropical and sub-tropical areas of the world. Anaplasms are known to exist in South, Central, and North Africa, Asia Minor, the East Indies, and North and South America.

This parasite takes the form of a minute spherical body usually found within and close to the margin of the red blood corpuscles. It is quite different in appearance from the piroplasm, which is usually pear-shaped. In the past, its existence has possibly been overlooked because it produces a disease very similar to redwater, and its appearance in the blood in association with the piroplasm has caused observers to regard it as possibly only a variety of the latter organism.

Dr. J. Legg, of the Animal Health Research Station, Townsville (*re* the establishment of which see this *Journal,* Vol. 5, May, 1932, p. 131), has for some time suspected that the anaplasm exists in North Queensland, but prior to the inauguration of the new régime the necessary facilities for pursuing these investigations were not available. Since his return from South Africa, a few months ago, however, he has addressed himself to the problem, and by a series of experiments has determined (i) that the anaplasm exists in Australia, often concurrently with the piroplasm, but from which it may be dissociated; (ii) that it is capable of producing a diseased condition of the host that may result in death; and (iii) that immunity to the one blood parasite does not imply immunity to the other.

The discovery is of importance chiefly in connexion with the immunization of healthy cattle introduced into the tick-infested areas of the North.

The presence of two diseases, both tick conveyed, on an individual property may account for the so-called "relapse" which may occur when cattle immunized against the redwater piroplasm are exposed to tick infestation, the "relapse" in this instance being due to anaplasmosis inoculated by the tick in the natural manner.

When one considers the long period of incubation which frequently occurs with anaplasmosis, an explanation is given to the "secondary reactions" which may occur after inoculation for redwater, these "secondary" or delayed reactions being due to the presence of the anaplasm in the blood used for inoculation purposes.

There is the possibility that tick-infested areas exist whether neither of the parasites exist, or where one alone may be present.

Dr. Legg's report will shortly be published by the Council as a special pamphlet.

White Ant Investigations in North Australia.

Mr. G. F. Hill, of the Division of Economic Entomology, returned towards the end of last year from a three months' stay in Darwin, where he went for the purpose of carrying out some investigations into the control of the largest and most destructive Australian termite (white ant), namely, *Mastotermes darwiniensis*. Particular attention was given to the insect's attack on dwellings and on living trees, and a considerable proportion of the work concerned the effect of various poisons.

Numerous tests were made with baits of sawdust and other cellulosic material after treatment with various poisons and with and without the addition of supposed attractive substances. It was found, however, that sawdust from *Eucalyptus gigantea* was more attractive than any other material tested. When such sawdust was mixed with from 1 per cent. to 3 per cent. of arsenite of soda, termites were destroyed, but it was found impossible to free an infested building of the insects in this way.

Fumigants and dusts such as paradichlorbenzene, sodium fluoride, Paris green, cyanogas, &c., were used in walls traversed by the insects, and also in the " tubes " or tunnels leading to the main nest. (Incidentally the nest of a colony of *Mastotermes* is extremely difficult to find and may be 100 yards or more distant from the site where insects are obviously present, the path between the nest and feeding place being an underground tortuous " tube "). Most of these materials were found to kill white ants readily enough, but their effects soon wore off, and other members of the colony soon returned. Paris green, however, was found to be very satisfactory. In one case, for instance, an occupied tube extending from the ground up the concrete foundation of a building was broken, and Paris green blown into it. For some weeks the termites which were left in the timber attempted to reconstruct the tube to allow of their return to the soil, but each attempt failed, and the result was the death of a great number of insects.

In the neighbourhood of Darwin, indigenous and introduced fruit and ornamental trees are frequently attacked by white ants. It was found, however, that Paris green used as a dust and blown into the centre of an infested tree from an auger hole bored into the centre at about 18 inches from the ground was quite effective. In all, about 100 trees, including about 46 citrus trees, and many mangos, poincianas, and indigenous Acacias were treated—in all cases with complete success. It is expected that the treatment will remain effective for many years.

In conclusion, Mr. Hill's work was greatly facilitated by the Australian Investment Agency, which, through its General Manager, Mr. C. W. D. Conacher, gave £75 towards the cost of the work as well as laboratory and other accommodation at Darwin, and clerical and manual assistance.

Wood Taint in Butter—Experimental Shipments.

In a previous issue (Vol. 5, Feb., 1932, page 1), an account of the Council's investigations into the problem of wood taint in butter, and of the spray treatment that has been developed for controlling it, was

given. Further tests of the process are now being carried out by means of small experimental shipments of sprayed boxes which are being used as part of an ordinary consignment of export butter.

Two timbers, namely, *Pinus radiata* (*insignis*) and hoop pine, are being employed in the tests. Boxes made of the former timber are being forwarded to London by the South Australian Farmers' Co-operative Union. The first shipment from South Australia, consisting of 90 boxes, left Australia early in 1932. The results of the London inspections were, on the whole, satisfactory, although a small amount of taint in the butter near the edges of the boxes was found. The boxes of this particular shipment, however, consisted of undressed timber, which did not give the treatment such a chance of success as if dressed timber had been used. Further shipments of boxes made up of dressed timber left South Australia in September and October last, and the results of the London tests should soon be available.

Small experimental shipments of butter in boxes from sprayed hoop pine have also been sent from Queensland by Messrs. Hancock and Gore. The first of these left Australia in August last, and was followed at short intervals by five others. The results of the London inspections of the first shipment have just become available through the courtesy of the Department of Commerce, being contained in a report of the Department's Dairy Officer located in London. The report reads as follows:—

> "A consignment of butter, packed in specially prepared boxes *ex* the s.s. *Bendigo,* was examined at the warehouse of Messrs. Foley Bros. on 20th October. A selection from the marked boxes was made of an equal number of treated boxes comprising veneer and sawn timber boxes. For comparative purposes, a number of untreated boxes were also brought to the warehouse.
>
> "Each box was emptied and the box and contents carefully examined. It was noted that in every instance the treated boxes gave off no smell from the inside and had a clean impervious surface. The edges and other surfaces of the butter were carefully inspected, and only in rare instances was the faintest trace of taint to be found on the most exposed of the edges. In one instance the paper had got doubled back, exposing several square inches of unprotected butter, but no trace of taint could be found. On this occasion, there was a most distinct difference between the treated and untreated boxes. While the treated boxes were free from smell and the butter on all surfaces almost completely free from taint, the untreated boxes, especially the veneer type, smelt like new leather. The taint could be found on most surfaces of the butter, but was particularly noticeable on edges, top side and bottom.
>
> "Should subsequent examinations of other consignments yield such satisfactory results, a considerable step towards the elimination of timber taint will have been made, but at this stage one cannot anticipate the result of future examinations."

In all cases of these experimental shipments, a few boxes are retained in Australia and opened up at about the time the main shipment should reach London. The butter they contain is then tested for wood taint. The results of this work to date have, as would be expected, been in line with the results of the London inspections.

A new Apparatus for Treatment of Wounds and Fly-struck Areas on Sheep during Shearing and Crutching Operations.

(*Contributed by Dr. J. A. Gilruth, Chief, Division of Animal Health.*)

The varied sounds of a shearing shed are frequently punctuated by the cry "Tar." Forthwith a youth speeds to the source, and dabs more or less ineffectually a black paste from an uninviting pot with a stubby brush on to a wound more than usually severe made by the shears or the hand pieces of the shearing machine. Often the operation is perfunctory. The application is supposed to sterilize the wound, stop bleeding, and promote healing. Ordinarily its effect is negligible, beyond a tendency to ward off flies. It has struck many observers as being an unsatisfactory procedure, but time does not permit of the more careful antiseptic treatment of such wounds which, after all, are comparatively rarely attended with serious results. Perhaps no animal could suffer such frequent wounding of the skin in similar surroundings with the same impunity as does the sheep. From time to time, however, outbreaks of blood poisoning and of tetanus follow, while it has been abundantly demonstrated that the most common means of entrance to the system of the microbe responsible for "cheesy glands" (caseous lymphadenitis) is through wounds inflicted during shearing. Therefore, if an effective, economical, and handy method of applying an antiseptic were available, many a pastoralist would adopt it and with benefit.

Such a method has recently been devised, and I have had the opportunity of witnessing it in practical operation at the shed of Mr. F. D. McMaster of "Dalkeith," while sheep were being crutched and treated for strike when necessary.

The apparatus consists of a small air-pump (driven from the engine) and a cylinder provided with a gauge placed where the attendant can observe the pressure which is maintained at from 50 to 75 lb. per square inch. From this cylinder, a ½-inch pipe is led throughout the shed about 10 feet above the floor and attached to the uprights of the holding pens. From this horizontal pipe three down pipes for each group of ten stands descend at intervals to within 2 inches of the floor. At the end of the down pipe is affixed about 12 feet of rubber tubing which leads to a spray-gun similar to those used for the spraying of paint. The gun is fitted with a trigger which, when pressed, permits a spray or a jet to be emitted at the will of the operator. While not in use, the gun rests on a convenient bracket out of the way. When the shearer calls out "Tar," the boy grasps the nearest gun and rapidly and effectively sprays the wound with the antiseptic solution contained in the gun. For wounds at shearing time, a 1 to 7 solution of phenyl is employed at "Dalkeith," but during crutching, when struck sheep may be found, the solution used is slightly stronger—1 part of phenyl to 6 of water. I treated personally a number of fly-struck sheep with this apparatus, and found it everything one could desire for rapidity of treatment as well as effectiveness in destroying the maggots, while the quantity of fluid necessary was reduced to a minimum. Contrary to general expectations, the flexible tube is never in the way, and the shearers engaged in crutching were unanimous in their expressions of approval of the new method.

The cost of the installation complete is relatively moderate; when once established, depreciation is small and the cost of operating negligible. No extra staff is required. It should be a special boon to all pastoralists who are liable to find a percentage of sheep struck when shearing or crutching.

Recently, the members of the Joint Blowfly Committee at Canberra had an opportunity of observing a demonstration on the treatment of fly-struck sheep, with a portable apparatus attached to the motor car of the maker. They expressed the opinion that the use of this apparatus would be very much more efficacious for the treatment of wounds at shearing time, and the treament of struck areas when crutching, than the methods hitherto in use.

The Investigation of "Coast Disease."

The Chief of the Council's Division of Animal Nutrition (Sir Charles Martin) has recently made some suggestions to the Executive Committee of the Council in connexion with the problem of "coast disease" which causes difficulties to raisers of sheep and cattle in certain parts of Australia. He points out that the problem exists on some thousands of square miles of coastal districts to the south of Australia extending from King Island in the east to beyond the western border of South Australia in the west.

As Sir Charles puts it "the general story dating back 50 years is that although stock may be fattened upon calcareous country during the spring and early summer, if kept upon it for more than a few months they become debilitated and die, but if removed to much poorer "ironstone" heath country on the elevations adjoining the calcareous flats they recover their health but become, from scarcity of food, poor. Sheep farmers find it impossible to run their business unless they have access to ironstone country."

After discussing previous work on the problem and indicating that the conclusions drawn from such work are very divergent, Sir Charles expresses the opinion that there is a variety of maladies included in the term "coast disease" and that as a first step in the solution of the problem these individual conditions should be sorted out and classified. From his own observations to date, he considers that the term has been extended, *inter alia,* to the effects of parasitism, a nervous disease producing ataxia called rickets by the farmer, a lethargy with muscular weakness proceeding to emaciation and death and affecting animals which may be in apparently good nutritive condition, and maladies due to various degrees of general and mineral starvation.

He suggests that a small committee composed of people experienced in different branches of science be set up in South Australia to direct an inquiry into the whole problem.

The Executive has approved of the above suggestion and is now making the necessary approaches with a view to having the committee formally established.

Investigations with New Apple Stocks.

As a result of his visit to Australia a year or so back, Mr. R. G. Hatton, Director of the East Malling Research Station, reached the opinion that it would be well worth while if some tests of apple stocks other than the Northern Spy were carried out in Australia. He felt that there was a possibility that a number of problems of the local apple

industry were due to the general use of the Northern Spy stock and that some of the stocks developed at East Malling might be more suitable for some Australian conditions. In addition, Mr. Hatton has at all times made it clear that he would be glad to accommodate selected Australian graduates whom it might be desired to send to East Malling for experience in that Station's methods.

Accordingly, when towards the end of last year the Queensland Committee of Direction of Fruit Marketing approached the Council in connexion with horticultural investigations in the Stanthorpe district and offered financial assistance in that work, the opportunity was taken to send such a graduate for a year's stay at East Malling. The graduate in question is Mr. L. A. Thomas, M.Sc., and he is now at the Station on a studentship awarded him by the Trustees of the Science and Industry Endowment Fund. On his return to Australia, he will be located at Stanthorpe as an officer attached to the Division of Plant Industry. The Committee of Direction will then undertake the responsibility of providing his salary for a period of three years.

He has recently made arrangements for sending out to Australia at a fairly early date a selection of what are considered suitable East Malling stocks. It is proposed to plant these in the Stanthorpe district in two or three different situations. It is hoped that the necessary small blocks of land will be provided by local producers through the Committee of Direction.

The Catologue of Scientific Periodicals—Supplement.

The "Catalogue of Scientific and Technical Periodicals in the Libraries of the Commonwealth" was published by the Council some three years ago, the entries contained in it, however, covering information given by libraries up to the end of the year 1928. As pointed out in a previous issue (Vol. 3, page 125, 1930), it is particularly useful in a country of such large distance as Australia for research workers and others to be able readily to ascertain which libraries contain the particular periodicals they desire to see, especially as such periodicals are often comparatively rare. It was to meet that purpose that the Catalogue was originally prepared and printed.

At the time, it was realized that for the Catalogue to be maintained at its full value it would be very necessary to keep it up to date by means of periodical supplements. Information *re* amendments and additions is now being obtained from the co-operating libraries with a view to publishing the first supplement at an early date. A large proportion of this information has, in fact, already been obtained and indicates that this first supplement will need to be somewhat voluminous and that it will approach in size one-quarter that of the original Catalogue.

The estimated cost of preparing and publishing a supplement of this size amounts to some £400. Owing to the present restricted financial resources of the Council, it was obvious that publication would be delayed for a considerable time if the Council bore the whole of the cost involved as it did in the case of the main Catalogue. Under the circumstances it was decided to approach various scientific organizations such as

Universities, Royal Societies, the Australian National Research Council, the Australian Association for the Advancement of Science, the Australian Chemical Institute, the Institution of Engineers, Australia, the British Medical Association, Chambers of Manufactures, the Institution of Architects, the larger Public Libraries, Field Naturalists Societies, and the Australian Museum, for contributions.

The response has been very gratifying and already some £250 has been promised with a few further answers yet to come. It has accordingly been decided to proceed with the editing and publication of the supplement in question as soon as possible.

Copies of the main Catalogue (price 10s.) are still available on application to the Council or to Messrs. Angus and Robertson, Sydney.

Recent Publications of the Council.

1. Since the last issue of this *Journal*, the following Bulletins and Pamphlets of the Council have been published:—

Bulletin No. 71.—" Investigations on Irrigated Pastures."

1. The Yield and Botanical Composition of an Irrigated Permanent Pasture under Various Systems of Pasture Management, by A. E. V. Richardson, M.A., D.Sc.
2. The Chemical Composition of Irrigated Pastures at Wood's Point, South Australia, by H. P. C. Gallus, B.Sc.

The bulletin contains two reports of work on mineral deficiencies in pastures carried out under the co-operative arrangement entered into by the Empire Marketing Board, the Council, and the Waite Agricultural Research Institute. The first report deals with the results of studies into the yield of a permanent pasture under irrigation, into the effect of cutting the pasture at intervals of 28 and 56 days, and into the effect of fertilizers. The stock-carrying capacity of 70 acres of a permanent pasture sown at the same time as the experimental area and alongside it was 16.2 sheep per acre throughout twelve months.

The second report deals with the chemical composition of the experimental irrigated pastures mainly from the point of view of their nitrogen and phosphoric acid content.

Pamphlet No. 36.—" Fibre Boards: Their Uses and the Possibilities of their Manufacture in Australia," (Division of Forest Products—Technical Paper No. 6), by R. F. Turnbull, B.E.

The pamphlet discusses the results of a study that has been made by Mr. Turnbull into the possibilities of using Australian hardwoods for the manufacture of fibre boards and the economic possibilities of the industry in Australia. A description is given of the various types of fibre board in common use in other parts of the world; a history of the growth of the industry is also included. It is shown that the present consumption of such material in Australia, is about 9,000,000 sq. ft. or 1.4 sq. ft. per head of population as compared with a corresponding figure of 7.5 per head for the United States of America. From these figures it is

judged that the Australian demand could no doubt be stimulated considerably. A plant suitable for Australia is described, and the estimated cost for an annual production of 27,000,000 square feet is given as 10s. 6d. per 100, the corresponding figures for annual productions of 9,000,000 square feet and 6,000,000 square feet being 14s. 9d. and 21s. respectively. The conclusion is arrived at that if by the establishment of a sufficiently large plant, production costs are kept low, the enterprise would warrant every encouragement.

Forthcoming Publications of the Council.

At the present time the following future publications of the Council are in the press:—

Bulletin No. .—"A Soil Survey of the Nyah, Tresco, Tresco-West, Kangaroo Lake (Victoria) and Goodnight (New South Wales) Settlements," by J. K. Taylor, B.A., M.Sc., F. Penman, M.Sc., T. J. Marshall, B.Sc. (Agr.), and G. W. Leeper, M.Sc.

Bulletin No. .—"Varieties of Wheat in Australia—A Catalogue with Pedigree or Source and a Genealogical Chart showing the Relationship of the more Important Varieties," by J. R. A. McMillan, M.Sc.

Pamphlet No. 37 of the Council for Scientific and Industrial Research and *Science Bulletin No.* 40 of the New South Wales Department of Agriculture. "The Sheep Blowfly Pest in Australia." Report No. 1 by the Joint Blowfly Committee (appointed by the Council for Scientific and Industrial Research and the New South Wales Department of Agriculture). Editors R. J. Tillyard, M.A., D.Sc., F.R.S., and H. R. Seddon, D.V.Sc.

H. J. Green,
Govt. Printer, Melbourne.